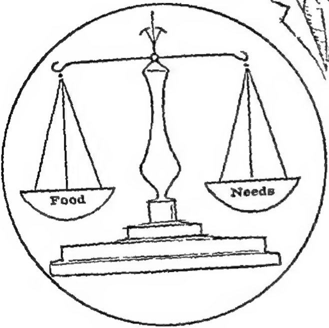

Nutrition

W. B. Saunders Company

Philadelphia and London *1960*

L. Jean Bogert, Ph.D.

and Physical Fitness

SEVENTH EDITION

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PREFACE TO SEVENTH EDITION

A NEW EDITION of this book always presents to the author both an opportunity and a challenge—the opportunity of including new scientific material and the challenge of presenting this material as simply as possible, employing new methods of presentation whenever possible, and treating current nutritional problems from a modern viewpoint

To carry out this task without unduly enlarging the book, much of the text has been rewritten, especially in Parts One and Two (Body Needs and Body Processes) Part One comprises more than half of the book and might serve as the text for a shorter course in Nutrition, if desired, it covers all essential nutrients, requirements and recommended allowances for each, and how to plan adequate diets for young adults, such as college students The scientific material in this section has been brought up to date, and considerable new material on metabolism and enzymes has been included in Part Two, as much as is suited to the understanding of students with no previous knowledge of chemistry The chapters on "Making Menus," "Family Food Budgets," and "Recent Trends in American Dietary Habits" have been condensed in part to make room for new material based on 1959 food prices, the most recent surveys of dietary habits in the United States, world-wide nutritional problems and the work of United Nations agencies

In presenting this new material, we have relied heavily on modern methods of visual instruction It is impossible to really understand nutrition without some knowledge of chemistry and the language of this science has now become part of our everyday life. It seemed to us that elementary college students could get an adequate conception of the chemical constitution of carbohydrates, fats and proteins, and even knowledge of what happens to these foodstuffs in digestion and metab-

olism, provided it was presented simply in the text and accompanied by simplified pictures and diagrams. Also, abstract ideas such as the balance within the body between intake and output of energy and other nutrients, and summaries of the uses and food sources of various nutrients would have added meaning and be more easily remembered if graphically illustrated. To this end, over 80 new illustrations have been added, including both half-tones of pictures obtained from United Nations agencies and other sources and nearly fifty line drawings made specially for this text by Mr William A. Osburn of Philadelphia, a medical illustrator. We are indebted to Mr Osburn both for cooperation in working out the author's ideas and for contributing original ideas.

The lists of Supplementary Reading at the end of each chapter have been revised to include latest available articles (through 1959). In the text, we endeavor to give students a concept of how scientific knowledge has grown by one discovery leading to another. Since most of the fundamental facts as to the essential nutrients, their functions and food sources, were built up in the period between 1910 and 1945, many of the footnote references bear dates of this era. Articles which present basic discoveries and the proof of their verity are never outdated, but represent milestones in the progress of nutrition. However, we endeavor to supplement these references by including in the supplementary reading lists references to some books and review articles that provide modern over-all discussion of a particular field, and citing recent articles that represent a cross section of current research in that field. It should be remembered that not all fields of research are evenly active. Some were worked out early and are relatively inactive at present, while research is especially active in other aspects of nutrition, notably in regard to intermediary metabolism and enzyme action, where much of the recent publications is too complicated to be translated for elementary students. It is a pleasure to acknowledge the courtesy of Dr Bessie B. Cook, of the University of California in Berkeley, for allowing the author use of her files and journals, as well as assisting in other ways in compiling the lists of supplementary reading.

Again the author expresses the hope that the intensive work and new ideas incorporated in this edition of "Nutrition and Physical Fitness" may make it better adapted to meet the needs of its many friends among both teachers and students.

L. JEAN BOGERT

Berkeley, California

FROM THE PREFACE TO THE FIRST EDITION

The purpose in writing this book has been threefold (1) To gather into a single volume facts useful in meeting everyday nutritional problems, which have been gleaned from the fields of food composition and economics, the chemistry and physiology of body processes, dietetics, and medicine (2) To make this information available to a comparatively large group by presenting it in such simple language as to be understandable to those with no previous knowledge of chemistry (3) To point out, in every instance possible, how such knowledge may be utilized for preventing ill health and promoting a high degree of physical fitness

In selecting subject matter, the aim has been to present the particular facts which anyone needs to know in order to build a sound body and maintain a high degree of health and vigor Many people, who are not actually sick, are distinctly below par physically—the so-called "80 per centers," although most of them probably have not attained even this high a proportion of the health and vigor which they might enjoy if better nourished Many children whose development is considered to be limited by heredity might make better growth and be free from physical defects if their nutritive condition were more favorable Our present high incidence of physical break-downs at middle age might be greatly reduced if people ate more sanely and moderately in earlier years Many American diets (those that consist too largely of highly refined, starchy foods, sugar, meat and potatoes) and modern living conditions are unfavorable for promoting good nutrition and health While not wishing to be an alarmist, one may conservatively say that the conditions which prevail are much in need of improvement The evidence to show the prevalence of poor nutritive conditions, their significance for health, and suggestions as to how they may be improved will be found in chapters on malnutrition,

obesity, constipation, diet after forty, modern trends in dietary habits, and the influence of factors other than food upon nutrition.

It seems advisable to add a few words to contrast the older mechanistic theory of nutrition with the broader, "physiological" conception which is gradually replacing it. To describe the body as a machine, food as fuel for the engine, certain constituents of the food as repair materials and lubricants, and the ever-interesting vitamins as the ignition spark which is needed to start the engine, may be very well as far as it goes but leaves too much out of the picture. It places too exclusive emphasis upon the food intake, and takes too little into account the body functions necessary to the utilization of that food, and the many complex variables which affect these functions The influence upon nutrition of body structure, of good or poor functioning of the various organs and tissues, of interrelations between the different parts of the body and between the body and external conditions, of habits of living and mental states, all need to be recognized In short, the body should be thought of, not as a machine, but as a complex, interacting, living organism, whose satisfactory cooperation in the task of maintaining good nutrition is of equal (but not greater) importance to health as is a food supply adequate to meet body needs. This complicates the problem but we think most of our readers will join with us in attesting the truth of the old maxim of Dr. Rabelais, "And if you desire to live in peace, joy, health, making yourself always merry, never trust those men that always peep out at one hole."

L. JEAN BOGERT

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PART ONE

Body Needs

CHAPTER ONE

Functions of Food and Its Relation to Health

NUTRITION MAY be defined very simply as the *science of nourishing the body properly*—that is, providing adequately for its *growth*, *maintenance*, and *repair*. Except for water and oxygen taken from the air, the needs of the body must be met by its intake of foods. Since foods supply the raw materials necessary for the upkeep of the body, it is obviously important that the right kinds and amounts of foods should be taken to supply *all* of the body needs. Nutrition is a science that holds vital interest for man, since it may be of great service in bringing about better health and even in prolonging life.

Instinctive Selection of Foods Does Not Always Lead to Good Nutrition

It is true that in many parts of the world peoples who know little or nothing of the science of nutrition have subsisted for generations on diets that maintained strong bodies. Sometimes, even on a limited variety of foods, those available were such that all the requirements for good nutri-

Figure 1 Primitive Alaskan Eskimo mothers rear numerous strong children, nursing their babies for about a year and remaining in excellent health meantime them- [illegible]

tion were provided Other primitive peoples were not so fortunate; either the food supply was inadequate or the racial habits prompted selection of foods that made an improperly balanced diet which lacked some factors necessary for growth and health.

McCarrison pioneered in this field by studying the diets used in different sections of India and their relation to the health of respective tribes. In the southern sections of the country, the diet consisted chiefly of milled rice, fruits, and vegetables, with little flesh foods or milk, these peoples were of smaller size and inferior strength, as well as short-lived. The peoples of tribes farther north, who used unmilled millet or wheat along with goats' milk and butter, had splendid physiques and the stamina to make good soldiers In remote sections of the Himalaya mountains races were found whose frugal diet was made up mostly of apricots (sun-dried for winter use), vegetables, and goats' milk, with meat eaten only on feast days; these peoples were unusually strong, healthy, and long-lived [1]

The Eskimos live largely on meat, but eat all parts of the animal, including the fat (blubber), organs, blood, and even ground bones, they are a healthy, hardy people and rear sturdy children The long-lived Balkan peoples eat little meat, but use whole grain cereals, cheeses, and the fermented milk known as koumiss. Studies of African tribes[2] have

[1] McCarrison, R, J A M.A., 78, 1, 1922

[2] Orr and Gilks, British Med Research Council, Spec. Report No 155, 1931

shown that, of two tribes living not far apart, one may have relatively large-sized and healthy bodies, while the other is puny and disease-ridden due to defective diet Two such tribes studied were the Masai, who tend herds and hence live mainly on meat and milk, and the Akikuyu, whose men eat chiefly corn and sweet potatoes, along with other cereals and vegetables. A full-grown man of the former tribe averages 5 inches taller and 23 pounds heavier than one from the latter tribe, and his muscular strength is 50 per cent greater. The diet of poorer classes in Central and South American countries provides too little protein and this almost entirely from beans and corn On such a diet young children, after weaning, often develop severe deficiency symptoms and those who manage to survive make less than normal growth (Fig. 3, p 6).

Recently there have been many suggestions that diet may be correlated, not only with physical stamina, but also with mental alertness and emotional stability In extensive studies on undernutrition, Keys[3] showed that changes in behavior and work capacity result from

Figure 2 Members of the African Masai [illegible]

[3] Keys, A , Brozek, Henschel, Mickelson, and Taylor, "The Biology of Human Starvation," Univ. of Minnesota Press, Minneapolis, 1950

Figure 3 A group of Guatemalan boys, showing stunted growth caused by the inadequate native diet, as compared with two boys of the same racial stock who had [illegible] type diet and are of normal weight and height for their age The boy at left [illegible] while the four boys next to him range from 5 to 7 years of [illegible] is nearly 7 years old; the three [illegible] to his right (approx same height) are [illegible] Guzmán, Institute of Nutrition for Central America and Panama [illegible]

prolonged underfeeding The World Health Organization, an agency of the United Nations, has made several surveys of the diet and nutritive condition of tribes in various sections of Africa, which strongly indicate a relationship between nutrition and behavior.[4] In Nigeria, Nicol[5] found tribes that lived near the seacoast (traders and fishermen, whose diets included fish) showed better health and mental alertness than inland tribes that depended solely upon vegetable farm products. He also calls attention to the fact that men of the farming tribe (Isoko) frequently appeared on police records as charged with rages and maniacal tantrums.

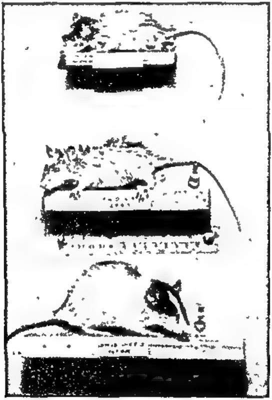
Incentives for Changing Food Habits

In the United States, which has the most plentiful and varied food supply of any country, one does not often encounter cases of severe malnutrition, yet the general nutrition level is not as high as might be expected and it could undoubtedly be improved by food habits that are guided by the newer knowledge of nutrition. Statements as to how large a proportion of the people are sub-standard as to their nutritional level will vary according to how high a standard is set for the "normal" We have no reason for complacency when surveys of school children show

[4] Reviewed in Nutrition Reviews, "Nutrition and Behavior," 12, 237, 1954.
[5] Nicol, B M, J Clin. Nutr, 1, 364, 1953.

that about 20 per cent of them may be under weight or have other visible evidences of malnutrition The important consideration, as a motivation for better food habits, is that the general health and vitality of even those persons who appear to be reasonably well nourished could be improved by their having even a better diet It is necessary to appreciate that science has proved that an already adequate diet can be improved and that this course will pay dividends in improved health

Sherman and his associates at Columbia University[6] established this fact by experiments on many generations of rats A basal diet that con-



[illegible]

equivalent of a jelly sandwich (white unbleached bread, jelly, pickle spread), vanilla [illegible]

California, Berkeley)

[6] Sherman and Campbell, J Nutr, 14, 609, 1937.

sisted of one-sixth dried whole milk and five-sixths ground whole wheat was found to be entirely adequate for the maintenance of normal growth, health, and successful reproduction of young, the colony prospered on this diet through more than fifty generations Yet when the proportion of dried milk in the diet was doubled (one-third milk to two-thirds wheat), striking improvements in "nutritional level" were shown in more rapid growth and development, greater vitality at all ages, and longer life

Numerous experiments made on school children have also demonstrated that diets which were at least fairly adequate might be improved by supplementary feedings One of the most striking of these was conducted on English school boys, 6 to 11 years of age, in an institution.[7] For a four-year period, one group received the regular institutional diet, while another group had the same diet supplemented with a pint of milk daily The group on the unsupplemented diet gained an average of 3.85 pounds in weight and 1.84 inches in height per year, in contrast, the group receiving supplementary milk showed an average annual gain of 6.98 pounds in weight and 2.63 inches in height Similar less well controlled experiments on large numbers of Scottish school children led to the same general conclusions. One group of 12,000 children received three-fourths of a pint of milk daily at school while an equal number were given no food to supplement their regular diet. The report states that the supplementary milk feeding "has a striking effect in improving physique and general health and in increasing mental alertness" Similar experiments with supplementary feeding in the United States have shown the same results, and surveys have shown a general correlation between the nutritional condition of children and their advancement in school[8]

The most recent and extensive survey of the eating habits of American school children was conducted in the late 1950's under direction of Home Economics staff members in various state colleges[9] Representative groups of children, in widely scattered regions of the country, were queried as to how often and how much they consumed of different types of food daily and weekly, in some places correlation was made with the physical condition of the children, in others not Although it is impossible to secure scientifically accurate records from children who eat at least two meals at home, the very large number of dietary records obtained, representing almost every state in the country, reveal some patterns of food habits among school children. In general, breads and cereals were eaten regularly and in satisfactory amounts, and meats

were consumed in satisfactory amounts whenever economic conditions permitted However, less than one-third of the children ate the amounts of green and yellow vegetables recommended for best health, less than half took the recommended quantities of milk, and about 40 per cent of them had less than recommended amounts of citrus fruits These last three groups of foods are often called "protective foods," since they reinforce the diet in those nutritive factors most likely to be below the "optimum" (best) level for health Usually younger children had a more satisfactory food intake than teenagers, with adolescent girls showing an especially poor record in milk consumption Although most children seemed in at least fair nutritive condition, obviously there is plenty of room for improvement of health and vitality through better food habits

Things That Stand in the Way of Improving Dietary Habits

Factors that militate against improvement of nutritional status through changing food habits may be briefly summarized as

Ignorance and prejudice
Racial habits
Fads and false advertising
Complacency
Poverty

The food habits of later life often stem from prejudices acquired in childhood, either from example of parents or from childish whims that are indulged Only education that explains why foods selected should include those needed to supply all the essentials for an adequate diet and conviction that better choice of foods will lead to more buoyant health will provide motivation to change old food habits for new ones This is especially true when food habits in the home are based on racial or religious practices, but such deep-rooted objections can often be met by suggestions that larger amounts of certain liked or permitted foods should be taken or that new foods may be cooked in well-liked ways Reducing fads and advertising literature that sponsors them may also induce a person to take unbalanced diets which furnish too little of certain nutritive essentials, advertising "boosting" of some types of food may persuade one to use such foods too largely and depend too little on other needed foods

Complacency is also a strong factor working against change of food habits Unless a person has a vision of the greater vitality to be attained by improving his food habits, he is apt to believe that he is well enough off as he is Lack of money to buy sufficient "protective foods" may be a decisive factor among low-income groups In such cases, some teaching of how to get the most in nutritive values for the money available is very important, and there must also be education as to why certain foods are essential for health In a recent review, Brozek[10] stresses that remote

[10] Brozek, J, "Nutrition and Behavior," Nutr Rev, 16, 257, 1958

sisted of one-sixth dried whole milk and five-sixths ground whole wheat was found to be entirely adequate for the maintenance of normal growth, health, and successful reproduction of young; the colony prospered on this diet through more than fifty generations. Yet when the proportion of dried milk in the diet was doubled (one-third milk to two-thirds wheat), striking improvements in "nutritional level" were shown in more rapid growth and development, greater vitality at all ages, and longer life

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(1) Carbohydrates	(4) Vitamins
(2) Fats	(5) Mineral elements
(3) Proteins	(6) Water

Carbohydrates, fats, and proteins are often spoken of as the *fuel foodstuffs*, since they are the only substances that the body can burn or use as fuel to supply energy for work and heat They belong to the great division of chemical substances known as *organic* compounds, which are combustible The mineral elements and water are sometimes called *inorganic foodstuffs*

Proteins, mineral elements, and water all enter into the composition of body tissues, and hence are necessary for *building new tissues* or repair of those already built Vitamins are chemically diverse organic substances which occur in minute quantities in foods but are essential for normal growth and health Certain ones may be built into or stored in the tissues, but their chief function is to serve in regulating body processes Mineral salts and vitamins act as *body regulators* by promoting oxidative processes, normal functioning of nerves and muscles, and vitality of tissues, and are of assistance in many other bodily functions Water also serves as an important regulating substance in the body It holds substances in solution in the digestive juices, blood, and tissues, and aids in regulation of body temperature, excretion, circulation, and many other body processes Vegetable fiber (cellulose), although not a true food substance, acts along with water to promote intestinal elimination

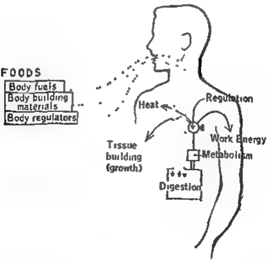

Figure 5 Diagram summarizing the functions of foods To qualify as a food, it must provide substances that either (1) act as body fuel to provide energy, (2) serve to build or maintain body tissues, or (3) act as regulators of body processes Many foods contain substances that serve all three purposes

goals, including longevity, can strongly influence choice of foods in the diet. With teenagers, a more immediate objective, such as the physical prowess, good looks, and charm that are associated with buoyant health, may prove more effective in stimulating interest in good food habits. Young college women, as prospective mothers, should be vitally concerned in good diets to safeguard their own health and that of their children, instead, they are often careless in eating habits or follow reducing fads in order to retain slender figures.

There is considerable evidence that dietary habits have been improving in the United States over the past two or three decades and that nutritional status, particularly of the younger generation, has been improving at the same time The *average* consumption of various foods in the "protective foods" class has been decidedly increased,[11] but of course many individuals still eat far less than "optimum" amounts of these foods Babies and young children grow faster and have sturdier bodies than before the knowledge of nutritional needs was as well understood as it is now Young people who enter college at the present time have been shown to be taller and a little heavier, although younger at time of entrance, than those who entered college thirty years ago Life expectancy has increased, for a number of reasons, so that there is now a far larger proportion of "oldsters" in the population One of the aims of nutrition should be to prolong the vitality of the "prime of life" into later years There is still much room for dietary improvement, provided nutritional teaching can convince people that alteration of their dietary habits is worth while

Functions of Food and Essential Nutrients or Foodstuffs

To nourish the body, foods must contain substances that *function* in one or more of *three* ways:

(1) furnish body fuel, substances whose oxidation in the body sets free *energy* needed for its activities

(2) provide materials for the *building* or *maintenance* of body *tissues*

(3) supply substances that act to *regulate body processes*

An individual food may fulfill all three of these functions or only one, but all three functions must be served by the diet as a whole in order to maintain the body in health Most foods can fulfill more than one function because they are *mixtures* of a number of chemical substances Any chemical substance found in foods that functions in one or more of the three ways named above is called a *nutrient*, or *foodstuff*

Six general classes, or *kinds of nutrients*, which are necessary to the body, are:

11 U. S Dept Agric Misc. Pub No 616, 1947; "Food Consumption of Households in the United States," U S Dept Agric, Agric Research Service and Institute of Home Economics, 1956

hydrate in nature and is listed as such Although this residue undoubtedly does consist largely of carbohydrates, it will also include organic acids (in fruits and vegetables), indigestible carbohydrates (cellulose and hemicelluloses) which have no food value, and various other undetermined substances not carbohydrates

In some cases, the crude *fiber* is determined separately, subtracted from the total carbohydrates, and the remainder listed as *utilizable carbohydrates* More accurate figures may be obtained by direct analyses for determining the carbohydrates through their reducing powers

Tables of food composition, obtained by the above methods, can never be absolutely accurate for several reasons First, certain errors are inherent in the methods used or in the manner of calculating results (as pointed out in describing the methods above) Then, even in the hands of skilled chemists, small errors occur which are magnified on calculating the composition from the basis of a small sample to a percentage basis for the food as a whole Lastly, and probably of most importance, foods may vary considerably in composition either in samples from different sections of the country, in different parts of the same sample, or especially in cooked foods where moisture and fat content are frequently variable When a large number of samples of some raw food material, such as flour, milk, or eggs, have been analyzed, *average* values are ob-

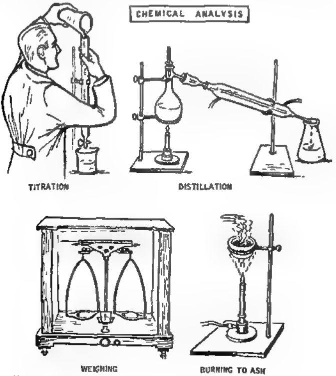

Figure 6 Some procedures used in the chemical analysis of foods

The three fuel foodstuffs—carbohydrates, fats, and proteins—can be used by the body more or less interchangeably to supply *energy*, depending on which is more abundant in the diet. These three classes of substances are by far the most abundant nutrients in our foods, minerals and vitamins being present in relatively small, or even trace, amounts All three are usually present in foods in the natural state, with some one of them predominating Thus grains have a high content of carbohydrate in the form of starch Lean meats are richest in protein, whereas fatty meats contain less protein and more fat.

For building tissues, different proteins are not interchangeable, since the "building stones," called amino acids, which compose them vary in kind and relative amounts Some 8 or 10 of these amino acids cannot be made in the body and must be supplied in the diet. Also some 10 to 15 different mineral elements must be supplied, either in major or minor amounts, and about 15 different vitamins are known to be needed, although not all of these have been proved to be essential for man. Hence, there are actually some 35 or more different substances that are essential for normal nutrition, but most of them can be grouped under the six classes of nutrients listed above

How Composition of Foods Is Studied

What nutrients and how much of each are present in our various everyday foods is usually determined either

(1) by chemical analysis, or
(2) by biological assay.

Chemical analysis provides useful data as to the approximate distribution of carbohydrates, fats, proteins, mineral matter, and water in any given food. It also enables us to determine with fair accuracy the amounts of such mineral elements as iron, calcium, phosphorus, sulfur, sodium, chlorine, etc., present in different foods Methods commonly used for determining the relative amounts of the foodstuffs, other than vitamins, are briefly outlined below.

Water is determined by weighing a sample of the food before and after drying to constant weight

somewhat in the amount of nitrogen they contain.

Fats are determined by extracting a dried sample of the food with ether With the true fats (weighed after evaporating to dryness the ether extract) will be included small amounts of other ether-soluble substances such as resins, waxes, and coloring matter (pigments)

Carbohydrates are usually determined by difference, that is, the remainder of the weight not accounted for under one of the above heads is assumed to be carbo-

several generations Such animals are fed a simple diet of known composition which is planned so as to provide plenty of all the essential nutrients *except one* A certain food is added to this basal diet in known amounts to serve as the sole source of the nutrient in which it is lacking and for which the special food is being tested

By such experiments, the existence of *vitamins* in natural articles of food has been established Likewise it has been discovered that numerous different vitamins are necessary in the diet for the well-being of man, and the relative amounts of each vitamin supplied by different foods has been more or less accurately determined Laboratory feeding experiments also give information, not obtainable by chemical anaylses, as to how *efficient* the *protein* content of different foods is for growth or maintaining weight, and how well *assimilated* and utilized the *mineral* content of certain foods may be Thus biological assay shows us how effective different foods really are in supplying the needs of the body for proteins, minerals, and vitamins

Some of the vitamins may now be determined by ***physical*** methods (measurement of absorption spectra, fluorescence, turbidity, etc), by ***chemical*** methods (chiefly by color reactions), or by ***microbiological assay*** (influence on growth of bacteria) However, feeding tests with animals retain their usefulness and in many cases are indispensable

Food Groups

The simplest and most convenient way to study the different common foods is to *group them in several classes* The foods grouped together are similar in chemical make-up and fulfill the same general functions in the diet Hence, if we learn to think of various foods in connection with

Food Groups According to Three Classifications

Ten Food Groups	*The Basic Seven*	*Four Main Groups*
Grain products	Bread, flour, cereals (whole grain or enriched)	*Bread-cereals group* inexpensive sources of energy and proteins Whole grains carry iron and certain vitamins
Potatoes and sweet potatoes		
Meats, poultry, fish, eggs,	Meat, poultry, fish, eggs, dry beans, peas, nuts	*Meat, poultry, fish, eggs, legumes and nuts* valuable sources of protein, some minerals and vitamins
Dry beans, peas, nuts		
Milk, cheese, ice cream	Milk, cheese, ice cream	*Milk and milk products* valuable sources of protein, calcium, other minerals and vitamins
Green and yellow vegetables	Leafy, green, and yellow vegetables	
Citrus fruits, tomatoes, etc	Citrus fruit, tomatoes, raw cabbage	*Vegetable-fruit group* chiefly important as sources of minerals and vitamins
Other fruits and vegetables	Other fruits and vegetables, incl potatoes	
Butter and other fats	Butter and fortified margarine	In addition, some fats and sweets are needed to round out the diet They supply energy and some fats (butter and margarine) also carry vitamins
Sugar, sirups, sweets		

Figure 7 Biological assay is used to show how efficient different foods are in supplying body needs for proteins, various mineral elements or vitamins. Rats are the favorite animal for feeding experiments, and the effectiveness of the diet in supplying body needs is gauged by relative growth and health of animals In the above picture, the animal fed Diet A obviously got the most complete and adequate diet, while the one on Diet D lacked some essential nutrient

tained from which individual specimens probably will not differ much in composition. With cooked foods, fruits, and vegetables, or whenever only a few samples have been analyzed, variations will be larger and figures less accurate.

Biological assay of foods is often used to determine their vitamin content, This method involves actual feeding experiments on laboratory animals (usually rats, guinea-pigs, or chickens) under controlled conditions. White rats, whose heredity and previous diet history are known, are considered the best "standardized" animals and hence are likely to give the most accurate results. Moreover, the chemistry of their body tissues is, for the most part, similar to that of man, and their life cycle is short enough so that one can watch the effects of some special diet on

vegetables Milk (3–4 cups for children, 2 or more for adults) and protein-rich foods (1 or more servings daily) are in specified amounts, while cereal foods, butter or fortified margarine are merely prescribed as "some daily." It should be understood that these seven "basic" groups do not constitute the whole diet, but will need to be supplemented with others (starchy foods, sugar, fats, etc) or extra servings of the specified groups, in order to round out the diet and provide sufficient energy

The Institute of Home Economics now recommends[12] planning the diet around four food groups, as shown in Fig 8 and listed in the right-hand column of the table on page 15 They call for 4 or more servings in the bread-cereals group (whole grain or enriched) daily, 2 or more servings in the meat group daily, and milk (or equivalent in cheese or ice cream) 3–4 cups for children, 2 or more for adults daily In the fruit-vegetable group, there should be a serving of citrus fruit (or other vitamin C-rich food) daily and a green or yellow vegetable at least every other day, two or more servings of other fruits and vegetables (including potatoes) are specified This simpler planning of the diet forms the *foundation* for a good diet As the bulletin states, "To round out meals and to satisfy the appetite many people will use more of these foods and everyone will use foods not specified—butter, margarine, other fats, sugars, other grain products"

QUESTIONS AND PROBLEMS

1 What is meant by nutrition, a nutrient or foodstuff, an adequate diet?

2 Why do some peoples prosper physically on diets consisting of only a few types of food, while others show physical degeneration on the limited types of diet that they take?

3 How is it possible to improve an already adequate diet and what benefits may be expected as a result of doing this? Name the chief motives for making changes in food habits indicated as nutritionally desirable, and some of the factors that stand in the way of changing food habits?

4. What are the three uses of food in the body? Name the six kinds of essential nutrients found in foods Which of these can serve as body fuel and why? Which are used in the building and repair of tissues? Which are necessary to regulate body processes?

5 Name the four general classes of foods suggested in the preceding chapter, along with the main contributions of each to the diet Name the seven food groups suggested as a basis around which to plan an adequate diet Why are green and yellow vegetables and citrus fruits listed as special classes here? Using foods from *each* of the four main food

[12] "Essentials of An Adequate Diet," Home Economics Research Report No 3, U S Dept of Agric, 1957

FOOD GROUPS

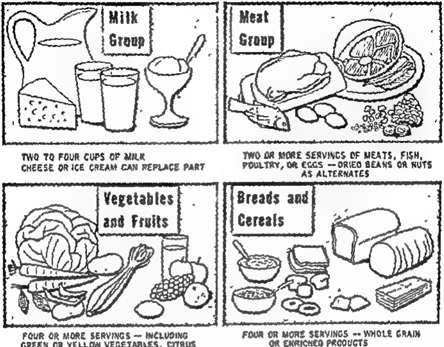

Figure 8 The specified number of servings from each food group together will provide a well balanced diet adequate in all nutrients, except extra fuel foods may be needed

the group with which they belong, we can easily substitute one food for another similar to it, avoid eating too many foods of the same class, and see that no one group is inadequately represented in the diet

Some food groupings in general use are shown in the table on page 15 The division into ten groups is that used by the Department of Agriculture in planning crops to fit the country's food needs, as well as for study of relative consumption of the different food groups It covers all classes of foods and it should be noted that fruits and vegetables are subdivided into four groups (potatoes, green and yellow vegetables, citrus fruits, all others), chiefly on the basis of their mineral and vitamin content

The arrangement of seven food groups (center column) was suggested by government agencies during World War II, as a means to planning an adequate diet The number of servings from each food group is specified (at least one, sometimes more) The subdivision of fruits and vegetables is retained (except potatoes are not in a separate group), at least one serving of green or yellow vegetables and one of citrus fruit or tomatoes are specified, with at least two servings of other fruits or

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Food Selection Check Sheet*

Credits			*Columns for Daily Check*						
MILK									
One cup of milk	10								
Second cup of milk	10								
Third cup of milk, or more	10								
		30							
FRUITS AND VEGETABLES									
One serving of green or yellow vegetables	10								
One serving of citrus fruit, tomato, or cabbage	10								
Two or more servings of other fruits and vegetables, including potato	10								
		30							
BREADS AND CEREALS									
At least two servings of whole grain or enriched cereals or breads		15							
MEATS									
One serving of egg, meat, fish, poultry, or cheese (or dried beans or peas)	15								
One or more additional servings of egg, meat, fish, poultry, or cheese	10								
		25							
		100							

* Courtesy of United States Department of Agriculture.

groups in the number of servings specified on page 17, plan a day's diet What other foods will be needed to round out the diet and satisfy energy needs?

6. Explain what is meant by the biological assay of foods. What information can be obtained by biological assay and how does it supplement facts obtained by chemical analysis? Describe how a food may be assayed for its content of a certain vitamin.

7. Make a record for 3–4 days of the kinds of foods (including beverages) and the quantities of each that you ate each day Check the amounts of each class of food consumed against those recommended in the check card above What foods did you eat in larger or smaller quantities than recommended as the basis for an adequate diet (to be supplemented with additional fuel foods)? How could you improve your dietary habits?

SUPPLEMENTARY READING

Aykroyd, W. R. [illegible] Developments," J [illegible]

Chenowith, L. [illegible] College Freshmen, [illegible]

Most proteins also contain some *sulfur*, and a few contain phosphorus, iron, or iodine in addition to the elements common to all proteins The "building stones" of proteins are amino acids, and on digestion each molecule of protein breaks down to yield many molecules of various kinds of amino acids Proteins characteristically have a "gluey" consistency and are precipitated or "coagulate" on heating

CARBOHYDRATES

Chemical Nature of Simple Sugars

Simple sugars form the basis for all carbohydrates and all of these compounds that occur commonly in food or in the body are either hexoses (6-carbon sugars) or multiples of hexose sugar groups So it is a good thing to see how the carbon, hydrogen, and oxygen atoms are linked up in a molecule of a typical hexose sugar, glucose The student should understand that every molecule of a given substance is exactly alike, with the same number of atoms of each element, linked to each other in precisely the same arrangement, any variation from this pattern makes it a different substance Each molecule of glucose consists of 6 carbon, 6 oxygen, and 12 hydrogen atoms, in other words, its formula is written as $C_6H_{12}O_6$ The carbon atoms each have four bonds, with which they can link up to other atoms or groups of atoms called radicals, in glucose, the six carbons use one or two of these bonds to unite with each other in a chain (or perhaps in an irregular-shaped ring) The bonds not used for linking up with other carbons are free to hold onto hydrogen atoms (which have only one bond) or a hydrogen-oxygen combination known as the hydroxyl radical (one bond), in this way they hold in combination in the molecule of glucose 6 oxygen and 12 hydrogen atoms. The other simple hexose sugars, fructose and galactose, both have the same formula ($C_6H_{12}O_6$) but the hydrogen and oxygen atoms are held in slightly different arrangements about the 6 carbon chain, which makes them different substances

Kinds of Carbohydrates and Their Occurrence

Carbohydrates are subdivided into three groups, according to the relative complexity and size of their molecules These divisions are of interest to the student of nutrition because the more complex carbohydrates must all be broken down by digestion into the simple sugar groups of which they are composed before they can be absorbed and used by the body These three classes are known as *simple sugars*, or *monosaccharides* (one sugar group per molecule), *disaccharides* (two sugar groups per molecule), and *polysaccharides* (many sugar groups per molecule) The linkage of sugar groups to form di- and polysaccharides is shown grapically in figure 9

Carbohydrates, Fats, and Proteins

THE THREE great classes of foodstuffs, carbohydrates, fats, and proteins, are so important both in foods and in the body that nutrition cannot be studied intelligently without some knowledge of their nature and occurrence

All *carbohydrates* are either sugars or more complex compounds, such as starch, which are formed by the union of many sugar groups. The class name is suggested by the fact that they are made up of the elements carbon, hydrogen, and oxygen, with the hydrogen and oxygen present in the same two to one proportion as in water.

Fats are also composed of carbon, hydrogen, and oxygen, but with these elements present in different relative amounts than in carbohydrates All true fats are alike in chemical nature and physical properties; they have a greasy feel, are insoluble in water but soluble in such solvents as ether, every molecule of fat yields on digestion one molecule of glycerol (an alcohol) and three molecules of fatty acids

Proteins consist of carbon, hydrogen, and oxygen, again in different proportions, and in addition they always contain the element *nitrogen*.

the fruits. Hence glucose, fructose, and sucrose are found chiefly in plant juices and in fruits The sweet taste of green corn and peas is due to the presence of sugar that is converted to starch as the immature seed ripens, in some fruits (e g, bananas) starch is present in the unripe fruit and turns to sugar on ripening Carrots, beets, onions, winter squash, turnips, and sweet potatoes are vegetables that contain appreciable amounts of sugars (as well as green peas and corn) Our sugar supply for table use and cooking comes chiefly from juices of the sugar cane or sugar beet, at least one-third of our supply now being derived from the latter source Chemically cane sugar, beet sugar, and maple sugar are all sucrose, the sugar made by hydrolyzing corn starch is the simple sugar, glucose, levulose and glucose occur in honey in about 50–50 proportion The sugar maltose is formed as an intermediate product during the digestion of starch in the body and is also found in germinated grains such as "malt," and in artificial products from partly digested starch such as corn sirups, malted breakfast foods, and malted milk Lactose occurs in the milk of all mammals, secreted as a source of energy for the young, on digestion it is broken down into glucose and galactose Disaccharides must be broken down into the simple sugars comprising them before they can be used by the body

Starch is formed by plants by union of many molecules of glucose and is the carbohydrate found in the seeds, tubers, and roots, where it is desirable to store energy for future use of the plant It has been estimated that the number of sugar groups in the starch molecule may average around 300–400, and there is evidence that they are arranged in a long, curving chain Such large molecules have no sweet taste and are not soluble in water Starch occurs in "granules' coated with a cellulose-

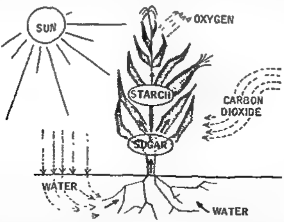


Figure 10 Synthesis of sugar from carbon dioxide and water through the agency of sunlight and the green pigment, chlorophyl, a process known as photosynthesis Sugar circulates in the plant sap, but excess not needed for immediate use is made into starch, which is stored in the maturing kernels of the ear of corn

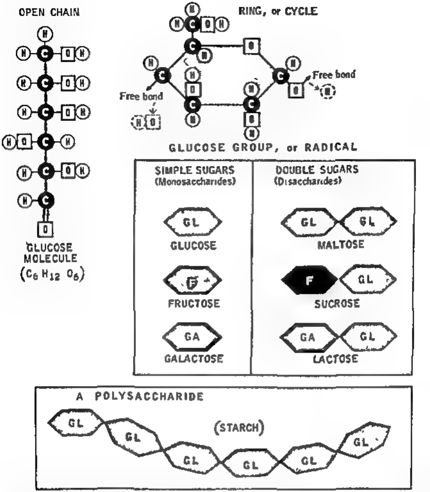


Figure 9 Diagram showing arrangement of the atoms in a molecule of the simple sugar, glucose, and in the glucose radical, also diagrammatic representation of the molecules of disaccharides and of a portion of the large polysaccharide molecule, starch

The carbohydrates most important in nutrition and the groups to which they belong are as follows:

Glucose, fructose and *galactose*—monosaccharides, or simple sugars,

Sucrose, maltose, and *lactose*—disaccharides, or "double" sugars,

Starch, dextrins, *glycogen, cellulose,* and hemicelluloses—polysaccharides.

to another in the sap or tuck it away for temporary use in the juices of

other pastries), legumes (beans and peas), and certain tuber and root vegetables (such as potatoes and sweet potatoes)

Cellulose is also a polysaccharide of glucose, more resistant to digestion and more insoluble than starch It is only softened by cooking processes and is practically indigestible for man, so that it is not a true food substance Cellulose and the closely related hemicelluloses make up the structural or fibrous part of plants (leaves, stems, roots, and seed and fruit coverings) and also the cell walls Since most of this material taken in plant foods remains undigested, it serves to give bulk to the food residues in the intestine and promote their evacuation Individuals vary in how much bulk they need to prevent constipation and whether they tolerate cellulose in rougher or only in softer forms

Glycogen is sometimes called "animal starch" because it is the polysaccharide stored in animal tissues instead of starch Its molecule is large but seems to vary somewhat in size Only limited amounts of glycogen can be stored in the liver and muscle tissues, and this is used up rapidly during fasting or muscular work When it is needed for use it is converted to glucose and then oxidized to yield energy Carbohydrate is an immediate source of fuel for animals, just as it is for plants For this purpose animals use glucose, which is the only sugar found in the blood or tissue fluids. Since animals have limited ability to store carbohydrate, there is little of it present in our animal foods, such as muscle meats Liver usually contains about 1 5 per cent glycogen, while shellfish (including oysters) carry 0 5 to 5 per cent

Carbohydrate-Rich Foods

Some typical foods of relatively high carbohydrate content, together with the approximate amount of carbohydrate each contains, are shown

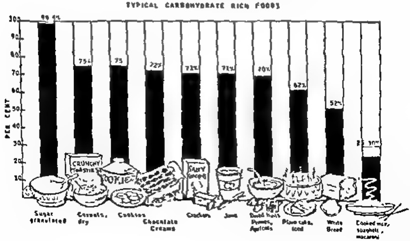


Figure 13

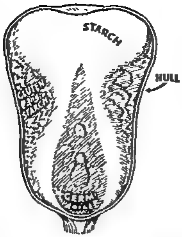


Figure 11 Diagram showing the structure of the corn kernel Starch is the principal component, the kernel containing about 60 per cent of this substance. In the starch manufacturing industry the gluten (protein) and the hulls are made into feed for livestock The germ contains a high percentage of oil, which, after purification, is used for salad oils and vegetable shortenings (Courtesy of the Corn Industries Research Foundation).

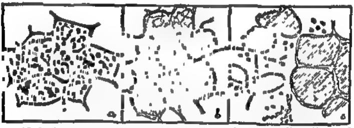


Figure 12 The potato—changes in starch granules and cell walls produced by cooking *a*, raw, *b*, cooked, *c*, thoroughly cooked (Courtesy of U. S. Department of *Agriculture)*

like substance, and different plants have granules of characteristic size and shape, so that the source of a starch can be determined by microscopic examination When subjected to moist heat (as in cooking), starch granules absorb water, swell, and are ruptured, after such treatment starch forms a colloidal solution in water, and, of course, it is more easily digested in this state Before starch can be used as a source of energy, either in the plant or in the body, it must first be broken down into the simple sugar groups of which it is composed, yielding molecules of glu-

made from them (breads, breakfast cereals, macaroni, and cakes and

The main contributions to the diet of carbohydrate-rich foods (sugars and starchy foods) may be summarized as follows:

(1) provide economical energy supply,
(2) furnish some proteins (grains and legumes);
(3) add flavor (sugar).

FATS

Composition, Occurrence, and Uses of Fats

All true fats are salts formed by union of fatty acids with an organic alcohol, called glycerol or glycerin The fatty acids contain large amounts of carbon and hydrogen, along with a relatively small amount of oxygen, and hence fats have very high fuel value They represent the chief form in which animals store extra energy for future use, as plants store energy in the form of starch Some plants store fats in fruits, seeds, seed germs, or nuts, as evidenced by the vegetable oils (from the olive, cocoanut, corn germ, peanut, or cottonseed) used for food However, most food fats are of animal origin—butter, lard, fatty meats and fish, egg yolk, cream, and full-milk cheeses An interesting fact is that fishes store fat instead of glycogen in their livers and so are sources of the fish-liver oils that are widely used medicinally for their valuable content of fat-soluble vitamins Butter-fat and the fats in egg yolk also carry fat-soluble vitamins, especially vitamin A

The *physical properties* of fats are important, are related to their composition, and sometimes affect their nutritive value That fats are insoluble in and lighter than water is easily apparent from the fact that the fat in milk is separate from the fluid portion and rises to the top on standing Fats that are in small droplets in a fluid (emulsified), as in milk and egg yolk, are more readily digested because the tiny droplets

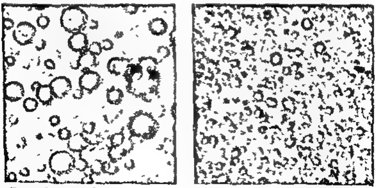


Figure 15 Fat globules in milk (left) magnified 1000 times, same in evaporated milk (right) broken up so fine that the cream will not rise (Courtesy of Evaporated Milk Association, Chicago)

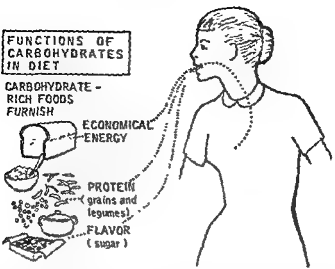


Figure 14

in the bar-graphs on page 25. A few highly refined articles, such artificially prepared foods as refined sugar and corn starch, are pure carbohydrate (with traces of moisture), but even those foods relatively rich in either sugar or starch contain in their natural state other substances besides carbohydrates Although highly milled rice or wheat (patent flour) are over two-thirds (66 per cent) starch, they also contain protein in amounts of 7.5–11 per cent Dry peas and beans carry over 20 per cent of protein along with approximately 60 per cent of starch, soy beans differ from other legumes in that they contain less starch and more protein and fat. The legumes and whole grains also contain some indigestible fiber, and certain minerals and vitamins

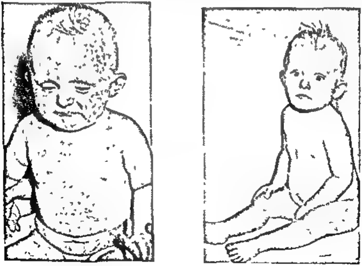
Foods of high sugar content (60–100 per cent) include table sugars, honey, sirups, candies, jams, jellies, preserves, and dried fruits (dates, figs, raisins, prunes, apricots), others containing appreciable amounts are fresh fruits (9–23 per cent) and soft drinks (9–12 per cent). Taken in considerable quantities, these last two sources may contribute appreciable amounts of energy (calories).

The grains (wheat, corn, rice, rye, barley) and dry products made from them are rich in starch (45–85 per cent), cereal puddings, potatoes, cooked legumes and cereals are of higher, variable water-content, so range in carbohydrate from about 10–20 per cent. Carbohydrate-rich foods usually provide the chief source of energy in low-cost diets (bread and potatoes) and countries less economically prosperous. In Japan, carbohydrates contribute ⅘ of the total energy intake; in the United States, where fats are used more liberally, only ½ (or less) of the energy intake comes from carbohydrates.

with respect to hydrogen, i e, they have type formulas like $C_nH_{2n-2}O_2$ (oleic acid), $C_nH_{2n-4}O_2$, up to $C_nH_{2n-8}O_2$. The more detailed structure of fats and of saturated and unsaturated fatty acids is shown in the diagrams in Figure 16 on page 28

When unsaturated fatty acids enter largely into the composition of a fat, the fat will have a relatively low melting point and be commonly encountered in fluid state, as an oil Some of these highly *unsaturated* fatty acids have been shown to be *essential to good nutrition*, but there is little danger of shortage of them in the normal diet On the other hand, chemists can get these acids to combine with more hydrogen (called hydrogenation of a fat) and by this process the liquid fat is converted into a solid fat It is by *hydrogenation* that cottonseed oil is converted into a semisolid state for use as a cooking fat (lard substitute) and other oils are changed to the consistency desired for use in margarines

Some fats are used as "spreads" and others in cookery Fats incorporated in foods give prized flavor and satiety value The *flavor* varies somewhat with the kind of fat used, individual preference being largely based on habit and economic conditions Since certain fats have become scarcer and more costly, the attitude of American consumers has altered to larger acceptance of formerly less used but cheaper fats, i e, nut or cottonseed oil instead of olive oil, and margarine instead of butter, at



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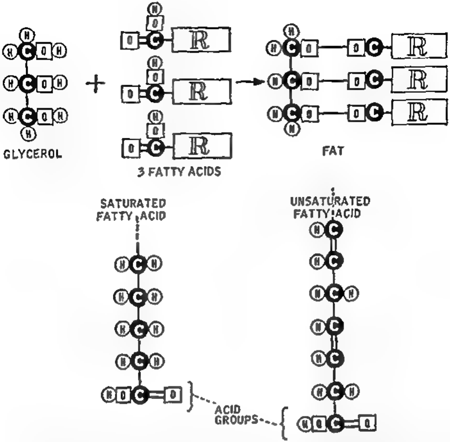

Figure 16 · Diagrams showing molecular structure of glycerol, fatty acids and fats Fatty acid molecules have a very long chain of carbon atoms with hydrogen attached, and at one end of the chain an organic acid group (COOH). Saturated fatty acids have only single bonds between carbon atoms in the chain Unsaturated fatty acids have one or several double bonds between carbons and can add on more hydrogen when these double bonds are broken and reduced to single bonds, hence they are unsaturated in respect to hydrogen

can be surrounded and attacked by digestive juices. Fats that are fluid at body temperature are more easily digested than those that have higher melting points. Every fat has its characteristic melting point. Fats known as "oils" are in fluid state at room temperatures, butter and lard melt on only a little heating, whereas mutton suet has the highest melting point among the meat fats, all of which are solids at room temperatures.

The difference in consistency at room temperatures (that is, the difference in melting points) is due to differences in the kinds and amounts of fatty acids that enter into their composition. *Palmitic* and *stearic* acids, which enter largely into the composition of solid fats, have a type formula of $C_nH_{2n}O_2$, they are said to be saturated because they cannot take up any more hydrogen. Some fatty acids are unsaturated

cause undesirable weight gains and place undue strain on the heart and other vital organs Insurance figures show that overweight persons have a much lower life expectancy than those who maintain normal weight for their height and age

Fatty Foods

Some typical fat-rich foods are listed in bar-graphs at the bottom of this page The principal foods that are almost pure fat are butter, margarine, vegetable oil, and shortenings such as lard, these are generally used in moderate amounts at a time, spread on or mixed with other foods low in fat content (e g , bread) Foods whose fat content ranges from 20 to 50 per cent (⅕ to ½) include cream and full milk cheeses, fat meats and poultry, chocolate, nuts, and peanut butter, these foods are also usually used in moderation Olives and avocados are the only fruits fairly rich in fat Pastries are somewhat difficult to digest, not because their fat content is so high, but because in them the fat is intimately blended with flour and other food substances, ice cream, with about the same fat content, is usually easily handled by the digestive tract

Fats and fat-rich foods are *useful in the diet* for three main purposes

(1) as a concentrated form of body fuel,
(2) for flavor and satiety value,
(3) as bearers of vitamin A

Lipoids

Lipoids are substances resembling fats in physical properties (soluble in fat solvents), some of which are chemically related to the fats They are usually associated with fats in the body and are important nu-

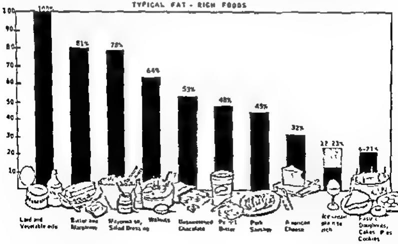

Figure 18

least in part. Since margarines are now made nutritionally equal to butter by addition of vitamin A (to the level found in average butter) and are permitted to be sold in colored form, their consumption has greatly increased

The *satiety value* of fats depends on the fact that fats slow digestion and the emptying time of the stomach, meals that contain considerable fat remain longer in the stomach and so prevent the early recurrence of the "hunger pangs" that occur when it is empty. This may be a good or a bad factor, depending on the amount of fat in the meal. When food is scarce or when one is on a "reducing diet," small or moderate amounts of fat are a help in preventing hunger; but when too much fat is taken, especially in so-called "rich" foods where it is intimately mixed with starch or protein, the meal may stay so long in the stomach as to cause severe indigestion It is better to use fats as spreads than incorporated in pastries, rich sauces, or fried foods that have been allowed to absorb cooking fat

Surveys of weekly food purchases of families in the United States,[1] made in 1955, showed that fats in the diet averaged 5.4 oz per person per day (as purchased, but probably much was discarded uneaten) and would furnish 44 per cent of the energy value of the diet This contrasts with about 39 per cent of the dietary energy furnished by fats in 1939 in the United States, and with 10–25 per cent in other countries where fats are scarcer and income levels lower Recently there has been much discussion as to the possibility that high fat intakes may be associated with the tendency to hardening of the arteries, high blood pressure, and coronary disease, also, there have been suggestions that a larger proportion of the fat intake should be in the form of those that carry unsaturated fatty acids Probably the actual level of fats in the diet is not as important as the total energy (calorie) intake, eating much fat often predisposes to overweight, which may lead to vascular and heart disorders. Those inclined to overweight would be well advised to cut the level of fat intake to about 25 per cent, at which level a normal variety of fat should provide sufficient unsaturated fatty acids.

Fat deposits in the human *body* may be either advantageous or disadvantageous, according to whether they are moderate or excessive. Whenever the intake of fuel foodstuffs exceeds current body needs for energy, the *excess is stored in the form of fatty tissues*, usually under the skin or about the abdominal organs, and serves a useful purpose as a *reserve store of fuel* to be drawn on in time of need. Moderate deposits of fatty tissue also serve to *support organs* and protect them from injury, and to *prevent undue loss of heat* from the body surface since fat is a poor conductor of heat. But an overfed person goes on storing fat which he may never need to burn as body fuel, such excessive fat deposits

[1] Dietary Levels of Households in the United States," Household Food Consumption Survey, Report No 6, U S Dept Agric , 1957.

ent in their tissues. Proteins are an essential part of every cell and tissue in the body, and make up about four-fifths of the solid matter in muscle tissue. If we ate no protein, the tissues would slowly starve to death, even though plenty of carbohydrate and fat were available to supply fuel.

The large molecules of the proteins are essentially a kind of "mosaic," made up of great numbers of relatively simple nitrogen-containing compounds called *amino acids.* To complicate the picture, some 12 to 18 different amino acids usually are found combined in a single protein molecule, linked together in an intricate pattern characteristic of the individual protein. At least 21 amino acids are known to be found in proteins and each molecule may contain several hundred of these units. It is not surprising that there are thousands of different proteins, special ones built by each plant or animal for the different kinds of tissues. Animals must break down the food proteins by digestion into the amino acid units of which they were built, then reassemble these units in such a way as to make the proteins characteristic of muscle tissue, gland tissue, blood, skin, etc. (see diagrams showing chemical structure of amino acids and their linkage to form proteins in Figure 21, page 34).

Although the body must get its nitrogen in the form of amino acids provided by the digestion of food proteins, not all of the 21 commonly known amino acids have to be furnished by the food. Some of the simpler ones can be formed in the tissues from what we might call the scraps left over when other amino acids are used up; these nitrogen-containing fragments are probably united with some simple substances formed in the course of tissue oxidation of carbohydrates and thus the nucleus of one amino acid may be used to build another. Some amino acids have a more complex nucleus which the body is unable to build. Certain amino acids which cannot be made in the body (or are made only in small

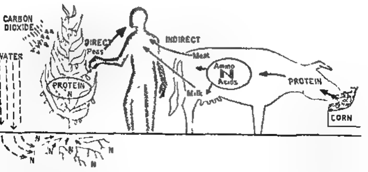

Figure 20. Plants build amino acids from simple nitrogen-containing compounds in the soil, carbon dioxide, and water; the amino acids are built into plant proteins, such

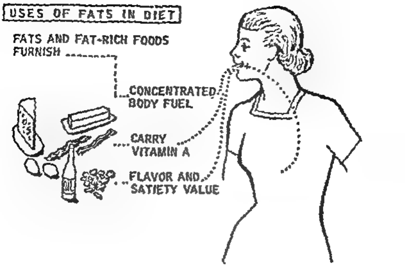

Figure 19

tritionally Since they are chemically more reactive than fats, it has been suggested that some fats may be converted to lipoid form for participation in life processes of the cells. They are found in all cells and are especially abundant in the brain and other nervous tissues, the liver, and blood Some of them, such as the *lecithins*, contain phosphorus and yield fatty acids and glycerol (along with other substances) when broken down by hydrolysis or digestion Others, like the *sterols*, are higher alcohols and resemble fats only in solubilities They are of interest in nutrition as precursors (mother substances) for one of the vitamins (vitamin D) and for hormones formed by the adrenal cortex and sex glands The fat-soluble vitamins E and K are also sterols.

PROTEINS

Nature, Characteristics, and Uses of Proteins

Proteins, which have larger and more complex molecules than either fats or carbohydrates, are substances that are essential to life; in fact, their name is derived from a Greek verb which means "to come first." In the definition of protein at the beginning of this chapter, it was stated that they are characterized by containing *nitrogen* (in addition to carbon, hydrogen, and oxygen), while some of them contain sulfur, phosphorus, iron, or iodine as well They are important to life as the only foodstuff that provides nitrogen Plants form their own protein from simple inorganic constituents of the soil, combined with carbon dioxide from the air, and water. Animals cannot utilize these simpler compounds to form proteins but must depend on the digestion products of the proteins taken in their food for the material from which to build the proteins that are pres-

amounts) must be supplied in the food and are said to be *essential amino acids.* Ten amino acids are essential to support growth in rats, but only 8 are needed for maintenance of full-grown men

Proteins that furnish a well balanced and complete mixture of amino acids, suitable for tissue building, are said to be of high *biological value* Other proteins, which may contain only small amounts or none of some one or more amino acids, are said to be of lower biological value, partially incomplete, and incomplete or deficient (according to whether they are low or completely lacking in some special amino acid) Complete and incomplete proteins, together with essential amino acids, will be taken up more in detail in Chapter [illegible]

Proteins can serve as *body fuel,* and they will be burned whenever an insufficient amount of carbohydrate and fat is provided in the diet to meet body needs for energy However, the primary use of proteins in the body is for *building or repair of tissues* Hence they are necessary for *growth,* and they are needed in relatively larger amounts by children and pregnant women

Proteins in Foods

Some typical protein-rich foods, together with their approximate protein content, are shown in the bar-graphs below

The reader will note that even the foods of highest protein content do not contain as much of this nutrient as carbohydrate-rich and fat-rich foods carry of carbohydrate and fat Although protein is a very valuable substance for both plants and animals, it is not required or stored in large

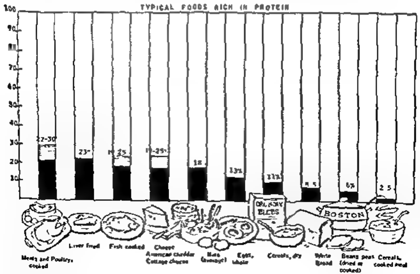

Figure 22

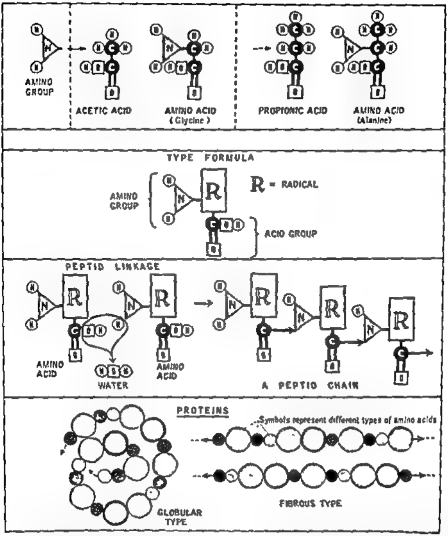

Figure 21. Diagrammatic representation of the arrangement of atoms in amino acids and the way they link up to form proteins (peptid linkage) The nitrogen is present in ... [illegible] ... protein molecules, small sections of which are represented in the diagram at bottom of the drawing above.

value Many peoples can get little animal protein and do very well on a variety of vegetable foods, supplemented by small amounts of animal foods. But in this country we stress the fact that, for adequate growth in childhood and for best health in later life, the protein in the diet should come from a wide variety of foods and a goodly portion (perhaps one-third) of it should be of high biological value, usually furnished by animal foods such as meat, eggs, and milk and milk products.

The protein-rich foods are *useful in the diet* for three main purposes:

(1) After digestion, proteins furnish mixtures of amino acids suitable for and essential to the *building and maintenance of body tissues,*

(2) Proteins furnish some fuel for energy needs,

(3) Most of the protein-rich foods also carry certain valuable minerals and vitamins

QUESTIONS AND PROBLEMS

1. Define carbohydrates, fats, and proteins What vital element is supplied in utilizable form to the body only by proteins? Why are these three classes of substances called the fuel foodstuffs? Which class supplies energy in the most concentrated form?

2. Name the three subdivisions of carbohydrates What is the chemical basis for division of carbohydrates into three classes? For each group or class of carbohydrates, give two examples of substances that belong in that group and instances of foods in which they are found. What happens chemically to starch in digestion?

3. What are the distinguishing properties of fats, i e, the qualities that would identify lard or salad oil as fats, in contrast to carbohydrates such as sugar or starch? What are the uses of stored fats in the animal body? Why are some fats hard solids, some soft solids, and some liquids at room temperatures? How do the unsaturated fatty acids differ chemically from the saturated ones? What is meant by hydrogenation of a fat? Name three foods that consist of vegetable oils that have been changed to solid or semisolid consistency by hydrogenation.

4 What are the chemical "building stones" of the proteins? Define an amino acid How many amino acids have been commonly found to occur in proteins? How many different ones are present in most proteins? How many are "essential" in the sense that they must be furnished preformed in the food? What is meant by the terms "high quality" or "high biological value" as applied to proteins? Why is it advisable that the diet contain a variety of proteins, some of vegetable and some of animal origin?

5 From bar-graphs on pages 25, 31, and 35 select three foods rich in carbohydrate that you use daily (or at least frequently), three rich in fat, and three rich in protein

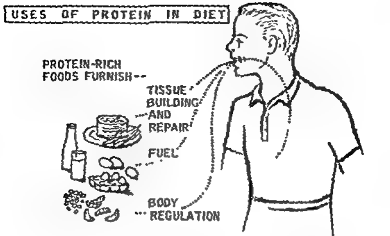

Figure 23

amounts Most of the animal foods contain fat and water (along with other substances in small amounts, almost no carbohydrate in meats). The vegetable foods contain considerable quantities of starch and some fiber. Milk contains some of all three fuel foodstuffs, as well as minerals and vitamins Even those foods that are relatively rich in protein contain only one-sixth to one-third protein (about 16 to 33 per cent in most meats, legumes, nuts, and cheeses) Milk and cereal products may, however, contribute appreciably to the protein supply when they are used in quantity. Nuts and legumes are normally used in rather small amounts, although gelatin is nearly pure protein in the dry state, the protein is in low concentration (2 5 per cent) in the gelatin jellies which are ordinarily used Grain products and legumes are our most economical sources of protein Milk and cheeses provide valuable proteins at moderate cost, whereas meats, eggs, and nuts are more expensive sources.

It should be remembered that, since protein is present in all living matter, practically all foods furnish some protein Those not listed in the chart (Fig 22) usually are of less than 10 per cent protein content, but many carry as much as 4 to 8 per cent protein. The protein content of vegetables other than legumes ranges from 1 to 4 per cent and that of fruits from 0 5 to 2 per cent If large amounts of these are eaten, they make a modest contribution to the total protein of the diet.

In general, the proteins in animal foods are considered superior in quality or of higher biological value than those in vegetable foods, i e., they furnish a better balanced and more complete assortment of amino acids. However, the proteins in one food (most foods contain several different proteins) can supplement those in another in their amino acid contributions. Even those incomplete proteins in vegetable foods contribute valuable amino acids, and some vegetable proteins (e g, those in soybeans and peanuts) have been shown to be of excellent biological

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Percentage Composition of Foods

	Water	*Protein*	*Fat*	*Carbo-hydrate*	*Ash*	*Fiber*
Bread	35 9	8 5	2 0	52 3	1 3	0 3
Butter	15 5	0 6	81 0	0 4	Ash consists of salt added	
Sugar	0 5			99 5		
Egg, whole	74 0	12 8	11 5	0 7	1 0	
Beef, lean round	67 0	19 3	13 0		0 9	
Beans, lima	66 5	7 5	0 8	23 5	1 7	1 5
Potato, white	77 8	2 0	0 1	19 1	1 0	0 4
Carrots	88 2	1 2	0 3	9 3	1 0	1 1
Oranges	87 2	0 9	0 2	11 2	0 5	0 6
Milk	87 0	3 5	3 9	4 9	0 7	

6 The table above lists the gross composition of ten common foods Select from this list three foods rich in carbohydrate but containing almost no fat, two that are good sources of protein but contain practically no carbohydrate, two that carry little or no protein, and one that contains all three foodstuffs in balanced proportions

From which classes of foods do we get most of our fiber and mineral elements (included in Ash in the table above)?

7 What are the three main uses, or contributions to the diet, of carbohydrate-rich foods? Of fat-rich foods? Of protein-rich foods? What are the disadvantages of using too much sugar? Of eating too many fat-rich foods at a meal? Why is a protein-rich diet usually more expensive than one that provides a lower level of protein? Can a vegetarian diet be adequate in quantity and quality of protein?

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Energy Needs: Basal Metabolism and Regulation of Body Temperature

WE HAVE already learned (p 11) that the nutritional needs of the body are for (1) *fuel foods that supply energy by their oxidation in the tissues*, (2) protein, (3) mineral elements, and (4) vitamins It is appropriate to begin the more detailed study of these nutritive essentials with consideration of the energy expenditures and requirements of the body. These energy needs are strikingly apparent, were the first nutritional factor to receive intensive investigation, and can be determined with greater exactness than those for the other nutritive factors. The necessity for fuel foods to supply energy in sufficient amounts to perform the work of the living organism is easily recognized, for without a sufficiency of energy-bearing foods a man burns up his own tissues and grows thin Although other food factors are of equal importance qualitatively, a shortage of them is not so quickly apparent, and the need for

energy is quantitatively the largest single nutritive factor. Finally, the energy requirement is ordinarily met by eating foods that also supply protein, minerals, and vitamins, if the foods are properly selected and consumed in amounts sufficient to meet the energy needs, the other nutritive factors may be supplied at the same time

Energy (in the physical sense) is usually defined as the *power to do work*, and the body needs energy because it has certain indispensable work to perform The energy needs of the average adult may be grouped under two main heads, namely

(1) for internal work,
(2) for external work

In addition, energy is *sometimes* needed for growth or tissue repair, or for heating the body The need for extra energy to build new tissue is confined almost entirely to the periods of childhood, pregnancy, or convalescence from wasting illness, and will be dealt with more fully in the discussion of these specific conditions (diets for children, pregnant and lactating women, and malnourished individuals) In the following chapter the *over-all* energy requirements of the adult, including amounts needed for external or muscular work, will be discussed in detail. Discussion in the present chapter will be limited to the *basic* energy requirements to cover *internal work* of the body and any possible need for heat to maintain normal body temperature

BASAL METABOLISM

Definitions

The word *metabolism* is a general term used to cover all the chemical changes that go on in the tissues of the body Under *energy* metabolism we include the physical changes by which energy is transformed from one kind to another in the body, e g , chemical energy in food is set free as work and heat when food is oxidized as body fuel

Basal metabolism represents the irreducible minimum of energy required to keep up the life processes, i e , for the internal work of the body It is usually defined as the amount of energy required by the body when lying at rest, relaxed, and without food (12–15 hours after the last meal)

Energy metabolism and requirements are measured in calories Since the energy that the body "spends" appears partially in the form of heat and the fuel value of foods may be determined in this form, it is convenient for nutritionists to use a heat unit as a measurement of energy. The large *calorie* (the unit used in nutrition) *is the amount of energy* (heat) *required to raise the temperature of one kilogram* (2.2 pounds) *of water one degree centigrade* (or 4 pounds of water one degree Fahrenheit) The abbreviation for the large calorie is C or Cal.

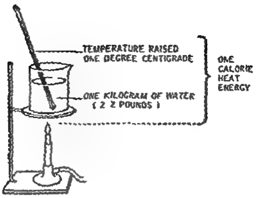

Figure 24.

Internal Work

The body is often likened to a machine which requires fuel or energy to keep it going A machine, however, needs energy *only* when it is doing external work, whereas the body never has any period when it is completely at rest It is a living organism most of whose tissues have to be continually active to maintain the life processes *It must work to live* This is evidenced by the fact that a living human body (even in sleep) is always warm, and only in death is the body cold.

About one-third of the energy necessary for maintaining the vital processes is used by different *organs* in their various activities, e.g, the beating of the heart, the work of the lungs and of the chest and diaphragm in breathing, the peristaltic movements of the stomach and intestines, and the work of glands such as the liver, kidneys, and digestive glands in forming their secretions But the greater part of the energy used to keep the body running, when a person is apparently completely in repose, is "due to oxidations in the resting tissues, principally in maintaining the *tone of the skeletal muscles*"[1] The *muscles* are never completely relaxed, and certain life processes go on in every cell even in sleep Thus the energy required to keep the life processes going, even at slower tempo, during an eight-hour period of sleep may be equal to the amount used by an inactive person for external work during the daytime, in addition the internal work of the body has to be maintained throughout the day.

This internal work of the body is known as *basal metabolism*, not only because it cannot be reduced further but also because upon it are superimposed the other energy needs of the body—the extra amount of energy needed because of intake of food and muscular work, and at times for the formation of new tissues. The basal energy needs are com-

[1] Sherman, H C, CHEMISTRY OF FOOD AND NUTRITION, p 154 Macmillan, 8th ed, 1952

paratively *constant* in amount for the same individual, but vary slightly at different times and in different persons

Two main factors determine how much energy the body will need for its internal work, or its basal metabolism, and the various conditions that affect basal metabolism may all be grouped under one of the following heads

(1) ***amount of active tissue*** in the body,
(2) ***intensity of the internal processes.***

Amount of Active Tissue

Muscle and gland tissues are active tissues, bones and fat are inactive tissues The chemical changes involved in the life processes of the cells go on rapidly in the active tissues and very slowly in the inert ones Hence muscles and glands use a considerable amount of energy in their day's work, while bones and fatty tissue require little energy for their up-keep Now what will determine the relative amounts of active and inactive tissues in the body of any given person? These factors are.

(1) Total size	(3) Sex
(2) Type of body build	(4) Condition of the body

It will be obvious that *size* will be a determining factor, since the body of a man who weighs 180 pounds will certainly contain a larger weight of muscle and gland tissue than that of one who weighs only 120 pounds, whatever the build of the two individuals But two men who weigh the same may differ in the amount of active tissues in their bodies. If one of them is tall and thin, he will carry more of his weight in active tissues, the other, who is shorter and stockily built, will have less muscle and more fat Even with the same height and weight, there may be differences in *type of body build* that influence basal metabolism A man who is large-boned and loosely built will usually carry less weight in inactive fatty tissues, whereas one of the same height and less broad-shouldered must be somewhat fatter to weigh the same Women require less energy for their basal metabolism than men do, not because of any direct influence of *sex* but because they usually have a larger proportion of fat in their bodies and smaller, more flabby muscles Of course, women also usually have a smaller total weight than men.

The factor designated *condition of the body* relates to previous habits of living and diet, which in turn have influenced the composition of the body A person who regularly takes a good deal of exercise will have less fat, more muscle tissue, and higher muscle "tonus" than one of sedentary habits, athletes have been shown to have a basal metabolism about [illegible] per cent higher than non-athletic men of similar size and shape. This means they need a slightly higher allowance of food to cover their basal needs, but their bodies are in better tone and health than when insufficient exercise is taken Likewise, a person who has been a heavy

eater (i e., has been accustomed to eating more fuel foods than are needed to meet his energy requirement) will have stored more fatty tissue than one who has eaten sparingly, and his basal energy requirement *per unit of weight* will be less than that of persons who are only moderately well nourished. Undue leanness, on the other hand, predisposes to a relatively high basal metabolism per unit of weight.

As a measure of the relative amounts of fatty and lean tissues in the body, specific gravity (determined by immersing the body in water and dividing body weight by the volume of water displaced) is claimed to be a truer index of amount of active tissues,[2] and hence of basal energy needs, than *average* basal requirement for normal individuals per unit of body weight Estimates of the amount of subcutaneous fat[3] in various part of the body may also be made from the thickness of folds of skin and fat pinched up in several places (under chin, on abdomen, chest, arms or legs), as measured accurately by calipers. By mathematical equations, "nonessential" body fat may be estimated from skinfold measurements The "educated pinch" has even been suggested for the uneducated layman as a general guide in judging over-fatness (obesity), if such a skinfold proves to be over an inch in thickness, it is an indication that weight reduction is called for

Although the total energy production for internal work (basal metabolism) and that per unit of body weight vary somewhat with the size, shape, and composition of the body, the influence of these factors disappears almost entirely when results of basal metabolism tests are reported in terms of calories *per unit of surface area* In adults, the basal heat production per square meter of body surface is remarkably constant, and hence this unit is frequently preferred to that of weight for reporting results On account of the difficulty of actually measuring the body surface area, it is usually computed from the body weight and height by means of a mathematical equation [4] The close correlation between internal work and surface area is explained by some as due largely to heat loss from the body surface and by others is thought to depend upon the fact that the total *volume* of body tissues bears the same mathematical relation to surface area as to heat production

Except for exact scientific studies, it is considered sufficiently accurate to estimate the basal metabolism of normal adults on the basis of body weight Whenever any of the various factors affecting basal metabolism obviously varies from the "norm," it is best to determine the

[2] Behnke, A R, Jr, *et al*, J A M A, 118, 495 and 498, 1942, see also reviews in Nutr Rev, 9, 344, 1951 and 10, 301, 1953

[3] Nutr Rev, 10, 246, 1952 and 13, 9, 1955

[4] DuBois, E F, BASAL METABOLISM IN HEALTH AND DISEASE, 3rd ed Lea and Febiger, 1936, or from a "nomogram" constructed from DuBois' chart by Boothby and Sandiford, given in Am J Physiol, 116, 468, 1936, or, less frequently, the "metabolic size" may be computed from body weight alone by formulas proposed by Brody in "Biogenetics and Growth" (Reinhold, 1945) and Kleiber in Physiol Rev, 27, 511, 1947.

basal metabolism of the individual directly (by basal metabolism test outlined on pp 49–50).

Intensity of Internal Processes

The rate or intensity of the internal processes of the body depends on these factors

(1) Age
(2) Secretions of ductless glands
(3) Sleep
(4) Muscle tonus
(5) After effects of { emotions and mental states, exercise, food, fasting }

AGE The intensity of the internal processes is greater in youth and decreases slowly with advancing age The term *basal metabolic rate* is used to describe the relative intensity of the life processes in the body The heart beat and respiration are more rapid, as are also the oxidation processes going on in the tissues, during infancy than in the adult

The basal metabolic rate is highest between the ages of one and two years, increasing from birth up to this time with the gradual development of muscle tonus After this there is a fairly rapid falling off in the rate of basal metabolism up to the fourth or fifth year, a gradual decline through later childhood, broken probably by a temporary rise in metabolic rate during the years of adolescence, and followed by a *very slow* progressive decrease throughout adult life

From the best current figures, it would seem that the basal metabolism *per unit of surface area* (see pp 44, 51) in adult life (30–40 yrs) is about 20–25 per cent lower than at its highest point in infancy (18 months) In the really aged (70–80 yrs) it shows a further decrease of about 10 per cent from the level found at the "prime of life" (30–40 yrs). In the age group 18–20 years (college students) basal metabolism is about 4 per cent higher than in the 30–40 year group

Based on *weight*, the basal metabolism of the young adult male of average size comes close to *one calorie per kilogram weight per hour*, which makes 24 calories per kilogram or about 11 calories per pound per day. The basal metabolism of women is lower, usually by 6–10 per cent, than that of men (p 43)

SECRETIONS OF DUCTLESS GLANDS [5] Quantitatively the secretions of the ductless glands constitute the most important factor in influencing

basal metabolism, and the secretion of the *thyroid* gland has a far greater influence on the rate of the internal processes than that of any other gland. Thyroxine, the iodine-containing substance secreted by the thyroid, has a very potent influence in speeding up all the oxidative processes of the body. When the thyroid gland is overactive it forms too much of this substance, and basal metabolism becomes much more rapid than normal, in abnormal conditions when the thyroid gland is underactive, the amount of thyroxine formed is too small to keep the basal metabolic rate up to what it should be. Thyroxine is so potent that 1 milligram[4] of it is sufficient to increase the energy metabolism 2–3 per cent, and a single administration increases the basal metabolic rate for 5–6 weeks, in a person who has little or no thyroid tissue. It is remarkable that in a person in normal health the amount of this potent substance secreted by the thyroid gland is regulated to such a nicety that the basal metabolism (energy output for internal processes) is kept at a constant and normal rate.

The internal secretion produced by the *adrenals*, two small glands situated just above the kidneys, also exerts an influence on basal metabolism, although not so markedly as does the thyroid secretion. Stimulation of the adrenal glands (such as happens in fright, excitement, and other emotions) causes a temporary rise in the metabolic rate, while it has been shown that cats have a fall of about 25 per cent in basal metabolism after an operation to remove these glands The pituitary and sex glands also have an indirect influence on metabolism.

SLEEP The chief effect of sleep in decreasing the internal work of the body comes through the accompanying relaxation of muscular tension It has been established that there is also some specific slowing down of the internal processes during sleep In adults, the average basal metabolism when asleep is about 10 per cent lower than when lying quietly but awake

MUSCLE TONUS. Everyone knows the difference between a condition in which the muscles are tense and one in which they are well relaxed Two facts most people do not appreciate are that the muscles are *never* completely relaxed, as maintenance of a certain amount of tension (spoken of as muscular tone or tonus) is necessary even in sleep, and that keeping up the normal muscle tonus involves considerable internal work. The amount of energy required for muscular tension will vary considerably with the degree of tenseness or relaxation of the individual, but the quantity needed always bulks large in comparison with the energy needed for heart beat, breathing, and other internal activities, because the total amount of muscle tissue is so great.

Any person who is under strain, nervous, and apprehensive will show a high degree of muscular tenseness. Even in the absence of such

[4] A milligram is one-thousandth part of a gram The gram is the weight unit in the metric system and is about 1/28 of an ounce, when translated into the English system of weights

conditions, the greatest degree of relaxation will be found on first waking and muscular tension will increase as the day advances For these reasons, it is best to make tests for determining basal metabolism early in the morning, to have the subject lie quiet for half an hour or more beforehand, and to further secure muscular relaxation by reassuring him that the test will not cause discomfort Even with these precautions, a second test will often give lower figures than the first (and therefore more truly represent "basal" metabolism), because muscular tension is less after the subject is accustomed to the apparatus and procedure

EMOTIONS AND MENTAL STATES. Emotions and mental states act on basal metabolism in several ways, probably the most important of which are through their effect on the ductless glands and on muscular tension It has been mentioned above that stimulation of the adrenal glands, such as takes place under emotional stress, results in an increased rate of body processes Many emotional states that involve fear or joy show an influence on the intensity of internal processes, and mental states also affect body processes, though usually to a lesser extent The most marked effect of mental strain seems to be in increasing muscular tonus, and the tenseness of the muscles during suspense, anxiety, or excitement, or even during mental work is a familiar phenomenon

EXERCISE Of course when we are talking of *basal* metabolism, or the energy required for internal processes only, exercise is ruled out, since basal metabolism always means metabolism at rest However, the ***after effects*** of severe muscular work persist for a long while after the work has ceased (see explanation of recovery from work or "oxygen debt," pp 77–78), and it has been found that the basal metabolism during the night that follows a day in which much exercise was taken, is higher than after an inactive day The oxidative recovery processes keep going on in the body for hours after severe muscular effort and for shorter periods after less strenuous work

FOOD The immediate influence of food is likewise ruled out in basal metabolism, which is always taken twelve to fifteen hours after a meal, but the after effects of food sometimes linger on into the resting period, as is the case with exercise The products of the digestion of protein food seem to stimulate or whip up metabolism, so that following a day when a great deal of protein has been eaten the basal metabolism is higher than it is after a day when the diet had been mainly carbohydrates and fats (see paragraph on influence of food, Chapter 4, pp. 58–60)

FASTING In *prolonged* fasting or semi-starvation the body seems able to adjust itself to a slightly lower level of metabolism in order to conserve its energy when a very limited supply of fuel is available The internal processes will thus be somewhat slowed down and the basal energy requirement will be lower after a long fast or in an adult whose food supply has been insufficient for his needs for some time This ad-

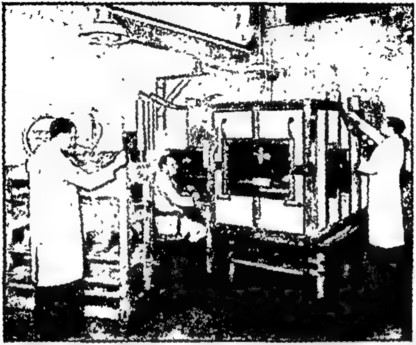

Figure 25 The respiration calorimeter now in use at the Russell Sage Institute of Pathology Such an apparatus permits both measurement of the gaseous exchange of the subject and direct determination of the heat which he gives off simultaneously. (*Courtesy of Dr E F DuBois*)

justment of the body to run with greater economy of energy does not occur in a short period of food deprivation.

During World War I, a group of 12 young men students volunteered for a prolonged period of underfeeding as to calories. Benedict[7] found that, when they had sustained an average loss of weight of 12 per cent, there was an average lowering of basal metabolism per unit of body weight by 18–20 per cent. More recent experiments in undernutrition[8] likewise showed an average 18 per cent reduction in the metabolic rate (together with a lowered expenditure of energy for exercise) on a daily fuel intake of 1500 calories But in undernourished children there is sometimes a higher than normal basal metabolism per unit of weight. Persons who are underfed as to calories suffer a loss of morale, physical strength, and endurance.

Measurement of Basal Metabolism

Naturally one is interested to know how it is possible to determine just how much energy is being used for the internal work of the body.

[7] Benedict, Miles, Roth, and Smith, Carnegie Institution of Washington, Pub No 280, 1919

[8] Mitchell, H H., "Adaptation to Undernutrition," J Am Dietet Assoc , 20, 511, 1944, Keys, A , "Human Starvation and Its Consequences," J Am Dietet Assoc , 22, 582, 1946.

That it can be measured with such exactness is one of the early triumphs of American nutritionists Although European scientists had devised apparatus by means of which the oxygen consumed and carbon dioxide produced by small animals could be determined (and the fuel oxidations in tissues computed), Atwater, Benedict and Rosa constructed the first "respiration calorimeter" for man at Wesleyan University in Connecticut between 1897 and 1905, and several more of these costly instruments were built later (in Washington, New York, and Boston). It is called a *respiration calorimeter* because in it can be measured not only the respiratory exchange but also the amount of heat given off by the human subject. The calorimeter portion of the apparatus consists primarily of a copper box large enough to hold a man comfortably, encased and insulated so as to prevent any loss through the walls of heat from within, the heat generated in the subject's body is carried away by water circulating through a coil of pipe near the roof of the chamber, so that the inner temperature is maintained constant The heat that leaves in the water and the heat required to vaporize water in the subject's breath (and perspiration) together represent the total heat production of his body in a given time This direct determination of heat produced is known as "direct calorimetry"

But at the same time, by devices included in the closed circuit of air which the subject breathes, the quantity of oxygen consumed and carbon dioxide given out are measured From these values, the amount of energy that would have been set free by oxidations within the body can be calculated, and this way of determining heat production is called "indirect calorimetry" By many very careful determinations in the respiration calorimeter, it has been established that values obtained by the two methods differ by only a fraction of 1 per cent

For this reason, we now find it practicable to measure basal metabolism by means of a relatively simple apparatus that determines only the respiratory exchange The use of a portable, easily operated *respiration apparatus* has made it possible to measure the basal metabolism of patients in bed, of students in the classroom, and of people in many parts of the world The determination usually consists merely in measuring the amount of oxygen consumed by the person when rebreathing in a closed circuit of oxygen-rich air for 6–10 minutes, then calculating the heat that would have been produced by this amount of oxidation in the body under the standardized conditions of the test The figure obtained is compared with the normal basal heat production expected for an individual of that height, weight, age, and sex (obtained from standard tables) Boothby and Sandiford found that in over half of the 102 normal adults studied by this method the determined value differed from the predicted one by only 1 to 5 per cent. Because of individual differences in body build, etc. (as well as of multiplication of small errors in computing results to an hour or day basis), variations of 5 to

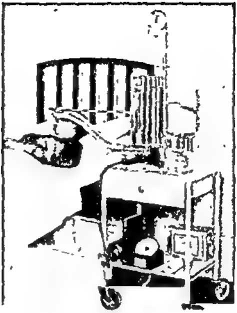

Figure 26 Benedict-Roth portable respiration apparatus for measuring basal

10 or even 15 per cent above or below the theoretical normal are not considered of great importance. In event of unduly high or low results (e g, —25, indicating 25 per cent below theoretical normal), the physician will look for the possible factor that is producing the variation from normal The abbreviation BMR is sometimes used to indicate the basal metabolic rate.

RATE OF HEAT LOSS AND TEMPERATURE REGULATION OF THE BODY

Factors Influencing Rate of Heat Loss

Naturally if much heat is dissipated from the surface of the body, more fuel will be required to maintain its normal temperature, which is considerably above that of the surrounding air under ordinary circumstances If heat loss from the surface is low, there will be no need to oxidize food material to maintain normal body temperature, since the heat formed as a by-product of even the internal work of the body (including muscular tension) will suffice. When external work is done, the amount of heat available (as a by-product of work) is still further increased The main factors which affect the rate at which heat is lost from the body surface are:

(1) The relative amount of body surface
(2) The presence or absence of a layer of fat under the skin
(3) The relative amount of insulation { clothing / shelter }
(4) The environment { temperature of the air / humidity of the air / movement of the air }

Relative Amount of Body Surface

By relative amount of body surface we mean the extent of surface area in proportion to the amount of body tissue. A child has a larger amount of body surface in relation to its total size than an adult has, the tiny infant having the largest relative amount of surface for its size. *Shape* of the body also influences the relative amount of surface. A tall, thin person possesses about $1\frac{1}{2}$ times as much surface area as a short, fat person of the same body weight. Since heat loss is through the surface, the body with a large amount of surface must generate more heat to maintain its normal temperature than one with a relatively smaller surface exposure (see Fig. 27).

Surface area is a less important factor in adults than in infants and

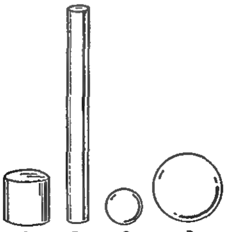

Figure 27. How size and shape affect the amount of surface area. The two

children, in whom there is a larger proportion of surface to volume. If too much of the body surface is exposed in children (or they are thinly clad and live in poorly heated rooms), they may be obliged to use for body warmth fuel which could otherwise be used to advantage for growth.

Subcutaneous Fat

We have spoken of the layer of fatty tissue directly under the skin, which is normal for most women. The extent and thickness of this layer of *subcutaneous fat* vary considerably in different individuals, according to sex, general build, and dietary habits. Fat is a very poor conductor of heat, or a good insulator, so that persons with a well developed layer of fat under the skin lose heat to the exterior much less readily than do those who have little subcutaneous fat. "Thin people have been proved to radiate fifty per cent more heat per pound than fat people; in other words, fat people are regular fireless cookers!"[9] Thus may be an advantage in winter but acts in the opposite direction in hot weather when, because the heat is held within by this layer of "packing," fat people are more subject to heat prostration, especially if they generate any extra heat within their bodies by exercise.

Insulation

CLOTHING. There are other insulators of the body besides fat. In summer, we leave some of the body freely exposed and wear loose clothing of porous weave and light color which allows heat to escape readily; in cold weather we resort to covering the body with several layers of clothing usually of thicker, less porous material and dark in color. Winter clothing usually helps considerably in conserving body heat. It might be worth while to point out that poor people, who are unable to get sufficiently warm clothing with which to protect themselves in winter, often become thin because their supply of food is apt to be limited and it is necessary for them to burn their own tissues to keep their bodies warm. The recent fad of young girls going scantily clad in winter, while eating as little as possible, may also bring about the same result.

SHELTER. The part which shelter plays is equally well known. Even primitive housing conditions protect somewhat from extremes of temperature and from exposure to the elements, but civilized man has now equipped his houses with heating devices so that summer heat can be maintained in them throughout the winter season. In fact with modern conditions of heating houses in the United States, the body is very seldom called upon to burn any of its fuel for the purpose of maintaining its normal temperature. Our latest developments in "air conditioning,"

[9] Peters, L. H., DIET AND HEALTH, p. 16. Reilly and Lee Co., rev. ed., 1939

which now permit homes and public buildings to be kept at constant temperatures both winter and summer, are a further factor in ruling out the influence of the seasons on body temperature

Environment

Cold-blooded animals like fish and frogs have no ability to regulate their body temperature, which accordingly rises and falls as the temperature of their environment changes Man and the other warm-blooded animals possess a heat-regulating apparatus which keeps the body temperature almost constant at a point which is usually considerably higher than that of their surroundings (98 6° F) Small variations of body temperature are normal, the normal range in health is about 2° F but variations ordinarily do not exceed 1° F

Under only two conditions do changes in the temperature of the environment have any effect on basal metabolism First, if the body surface is insufficiently protected from heat loss and the temperature of the air is sufficiently low, extra fuel must be burned to keep body temperature up to normal In such a case, there is likely to be shivering (involuntary muscular activity) and increased oxidative processes in the tissues (chemical heat regulation) to generate the extra heat needed, so that the basal metabolism will be increased

Conversely, in *fevers*, when heat loss from the surface is prevented, the temperature of the body itself will rise Since the rate or intensity of the internal processes is speeded up by a rise in temperature, the basal metabolism will be increased in this event It has been calculated[10] that the increase in energy expenditure is about 7 per cent for every degree Fahrenheit rise in body temperature, i e , a fever of 4 degrees (102 6° F) would call for 490 extra calories added to the basal metabolism of an average-sized man

The practical application of these facts lies in the knowledge that a somewhat larger supply of fuel foods may be needed in winter, especially if the clothing is insufficient or if there is considerable exposure, while in so far as is possible extra food should be given to fever patients to meet their increased demands for energy

Normal Heat Regulation

Temperature regulation is ordinarily accomplished in the body without effect upon the basal metabolism (physical regulation) or total energy needs Excessive heat loss is prevented (either by clothing, shelter, fat layer, or high temperature of air), and the heat produced as a by-product of body processes and muscular work is more than sufficient under these circumstances *Heat regulation thus is usually a problem of*

[10] DuBois, E F, Basal Metabolism in Health and Disease Lea and Febiger, 3rd ed, 1936

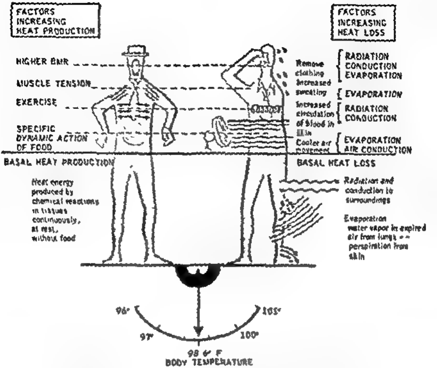

Figure 28 Diagram to show balance between factors that cause heat production in and heat loss from the body, thus effecting normal regulation of body temperature.

getting rid of the surplus heat produced About 80 per cent of this excess heat is dissipated by loss at the body surface, or through the skin. Some is lost through the lungs by evaporation of moisture in the expired air, and a small amount is lost in the excreta (for diagram indicating the various ways of effecting heat balance see Figure 28)

Heat is lost from the skin by (1) *radiation* or *conduction* and (2) by *evaporation* of moisture (invisible or visible perspiration) The relative ease with which heat can be got rid of from the skin by one or the other of these two paths depends on the surrounding conditions Low temperature of the air favors heat loss by conduction, whereas high temperature of the air cuts down heat loss by this means and favors loss by evaporation Low humidity aids evaporation and high humidity reduces the opportunity for loss of heat through this channel Wind or circulating currents of air favor heat loss by both conduction and evaporation. A further aid in temperature regulation is the variable amount of blood sent to the surface under different conditions of heat and cold, the skin becomes flushed on a hot day and blanched or bluish on exposure to cold. These facts are so familiar from experience as to need no further emphasis The important fact is that only under exceptional conditions

does the adult[11] need any extra fuel for maintaining normal body temperature.

QUESTIONS AND PROBLEMS

1. Distinguish between energy in the objective sense (as used in science) and energy in the subjective or psychological sense (feeling energetic). In which sense is the term always used in nutrition? What is the unit used for expressing quantitatively the energy values of foods and energy needs of the body? Define the large calorie and give abbreviations for it. Why is the calorie, a heat unit, used for expressing energy values?

2. Under what two main heads may the energy needs of the body be grouped? For what activities does the body require energy for internal work? Which requires a larger amount of energy per day—the muscular contractions of the heart or normal tonus of the skeletal muscles, and why? Can muscular tension ever be completely eliminated? What circumstances increase muscular tension?

3 Define basal metabolism Describe briefly the methods by which it may be determined, by "direct calorimetry," and by "indirect calorimetry" using some type of portable respiration apparatus How closely do results obtained by the two methods compare? What is meant by reports of +15 and −20 obtained as results of basal metabolism tests?

4 Name six of the factors that have an influence in determining basal metabolism, explaining how and why each has the effect that it does What four factors have the most important influence on basal metabolism?

5 In comparing the basal metabolism of adults, will it be more constant when compared on the basis of unit of surface area or on the basis of body weight, and why? Fill in the blanks in the following statements with the words "higher" or "lower," whichever would be true in the given case, and give reasons for your answer

Basal metabolism per unit of body weight (kg or lb)
will be in a 2-year-old child than in a 20-year-old woman
will be in a woman than in a man of the same age
will be [illegible]
will be [illegible]
will be [illegible]
will be [illegible]

6 Describe the methods by which heat loss is brought about by physical means What happens when chemical regulation of body temperature is called into play, and under what circumstances will this be necessary? Why is it not necessary in the calculations of energy needs

[11] Infants and young children may require some energy for maintaining normal body temperature unless the surface of their bodies is adequately protected from heat loss (see p 52) Elderly or sick persons, whose vitality is low, may also suffer undue heat loss unless warmly dressed or in a warm room.

under ordinary circumstances to make any allowance for energy to maintain normal body temperature?

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Total Energy Requirement of Adults

No person could live for long on the basal level of energy requirement The ordinary activities of life necessitate moving about, which involves muscular work Even holding the body in sitting or standing posture requires some muscular work, as do the minor movements that all of us are constantly making even when sitting at rest or during sleep Some persons take active exercise or must do muscular work in earning their living What is more, everyone must eat, and the taking of food in itself raises the energy output The *total* energy needs of the adult thus fall into three categories

(1) to meet the basal metabolism,
(2) to cover the effects of food,
(3) to do necessary muscular work

The energy needs for basal metabolism have been discussed fully in Chapter 3.

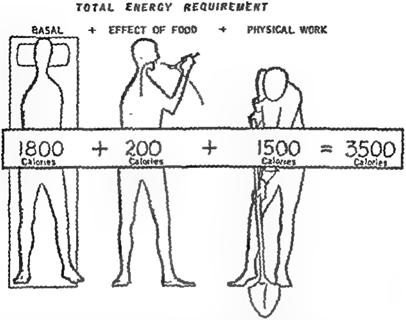

Figure 29 Total daily energy requirement for a man slightly above average weight (165 lb) who takes considerable muscular exercise, either at work or in leisure time Note the three categories that must be provided for and the relatively large increase in the calorie requirement caused by physical work

ENERGY NEEDS ABOVE BASAL REQUIREMENT

Effects of Food

DuBois has aptly likened the effect of food on metabolism to a tax, deducted at the source, which thus reduces the amount of a man's income, we do not derive the full fuel value of the foods taken in because a small portion of this fuel goes to cover the energy "cost" of their metabolism This energy deduction in metabolizing fuel foods is due, not to the fact that energy is required to digest the food, but to the fact that the products of its digestion, after they are absorbed, stimulate the "fires of metabolism" in the tissues to burn more brightly In the case of the digestion products of the fats, energy metabolism seems to be increased mainly because a larger amount of oxidizable material is brought to the tissues by the blood Carbohydrates seem to act in a different way, i e, heat is produced by the chemical reactions required for their metabolism in the tissues Proteins may act in a similar manner, although it is generally thought that the heat by-product of metabolism of amino acids is related to the splitting off of nitrogen as ammonia and formation of urea as the end-product of nitrogen metabolism[1] The stimulating effect of the foodstuffs on energy production (different for each of the three

[1] Wilhelmj, C M, "The Specific Dynamic Action of Food," Physiol Rev, 15, 202, 1935

classes) is called their *specific dynamic action,* which for convenience is often referred to as SDA.

The rise in metabolism after eating carbohydrate food will be only 6 per cent of the total fuel value of the food eaten (106 calories "spent" for every 100 calories of carbohydrate consumed), and the increase caused by fat is not very different in magnitude. The rise in metabolism after taking 100 calories of protein is much greater, however, amounting to 30–40 per cent, or 130–140 calories energy output[2] If the diet contains a great deal of meat, the day's increase in metabolism may amount to 18 per cent, or even more However, on the ordinary mixed diet, the usual allowance to cover the stimulating effects of the food itself is about 10 per cent of the total intake DuBois thinks that [illegible] per cent is sufficient allowance for the influence of food on a *mixed* diet, more recent experiments[3] comparing effects of high-protein and high-carbohydrate diets on man, found the specific dynamic action to vary between 10 and 17 per cent of total calories eaten Thus, in order to have his energy intake equal to output so that weight is maintained, a man whose energy needs for internal work plus muscular work amount to 2000 calories would probably require about 200 extra calories to cover the effects of the food

Aside from making necessary this extra allowance to cover the in-

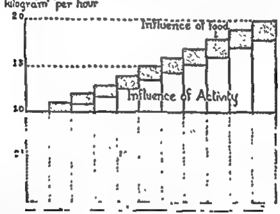

Figure 30 Distribution of energy expenditure and its increase with varying degrees of muscular activity

A—basal lying still, no food
B—lying still, with food
C—*sitting absolutely still*
D—confined to bed
E—sitting up, at ease
F—standing relaxed
G—standing "at attention"
H—singing
I—dressing
J—ironing (with [illegible] lb iron)
K—walking slowly (about 1 mi per hr)

(From Taylor and MacLeod, FOUNDATIONS OF NUTRITION, 5th ed, Macmillan, 1956)

[2] Lusk, G, "The Specific Dynamic Action," J Nutr, 3, 519, 1930
[3] Glickman, Mitchell, Lambert, and Keeton, J. Nutr, 36, 41, 1948

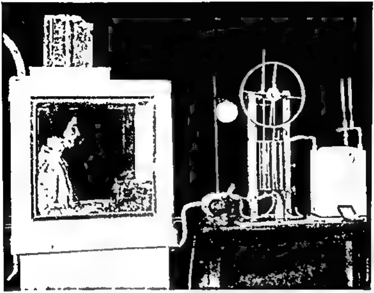

Figure 31 Determining energy expenditure during light muscular work such as typewriting (Courtesy of the Nutrition Laboratory of the Carnegie Institution of Washington, Boston, Mass)

crease in metabolism caused by the food, the chief significance of these facts lies in the observation that more protein may be included in the diet in winter or cold climates The extra energy set free in the body under the stimulating influence of the protein can be utilized to keep the body warm, although it cannot be used for doing work Conversely, the eating of much protein in hot weather is inadvisable, since the extra heat generated adds to physical discomfort at a time when it is difficult to get rid of surplus heat

Muscular Work

Muscular work is *by far the most important* of those factors which raise the energy requirement of adults above the "basal" amount needed at rest Whenever muscular work is done, energy is used up or "spent" and the amount required is proportional to the work done Smaller quantities of energy are needed for maintaining the body in sitting or standing position, while active work, such as walking, climbing stairs, pushing or lifting objects, requires a great deal larger energy expenditure The heavier the person moving about or the greater number or size of muscles involved, the larger the amount of energy that is required Thus walking, even at moderate pace, will require more energy than typing rapidly

If the energy metabolism of a man sitting still is estimated at 100 calories per hour, the metabolism of the same man *when working* may range from 300 to 600 calories per hour, according to the amount and

kind of work done. To get an idea of how much larger the increase in energy need resulting from external work is than that resulting from any other factor, compare this 200–500 per cent increase in metabolism due to active work with the 6–10 per cent increase due to the influence of food.

Of course such an active energy output cannot be kept up for very long at a time, so that the total increase in energy requirement for the day (working eight hours) will not be more than 50–100 per cent over the maintenance requirement even for active workers. In an inactive (sedentary) man or woman the distribution of the energy used during the day is usually about two-thirds for the internal work of the body and one-third for visible muscular movements. As soon as more exercise is taken, however, the energy required for external work mounts rapidly, while that needed for body processes remains constant. Thus the proportion of the energy used for visible work may come to be as much as three-fourths of the whole, and the total amount of energy needed will be increased until it may be nearly tripled in event violent exertion is involved.

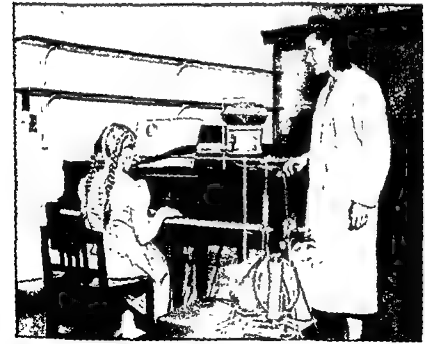

Figure [illegible]
energy ex [illegible]
less for [illegible]
(Courtes [illegible]

Estimations of the total fuel requirements for persons in occupations that involve different degrees of physical activity will be found in the table below. A man whose daily work is chiefly done standing or walking (e.g., a carpenter or mason) will require approximately $1\frac{1}{4}$ times as much energy as one whose occupation is performed sitting (e.g., a bookkeeper or machine operator in a factory). A farm laborer will need $1\frac{1}{2}$ times and a ditch-digger or lumberman about $1\frac{3}{4}$ to $2\frac{1}{2}$ times as much energy as the sedentary worker. This means, of course, that those who perform tasks requiring physical exertion must take more food in order

Daily Energy Requirement According to Occupation

Type of Occupation	*Total Calories per Day* — *Men*	*Women*	*Cal. per Kg per Day*
At rest but sitting most of day	2,000–2,200	1,600–1,800	30–33
Work chiefly done sitting	2,200–2,700	1,900–2,200	34–37
Work chiefly done standing or walking	2,800–3,000	2,300–2,500	38–42
Work developing muscular strength	3,100–3,500	2,600–3,000	43–50
Work requiring very strong muscles	4,000–6,000	—	55–70

to provide the added energy needed for external work, and the greater the amount of work done the greater the amount of food needed

It is difficult to generalize concerning fuel needs at various occupations or trades, since not only do the workers vary in body weight and rate of working, but under modern conditions jobs in the same industry often involve widely different amounts of physical exertion. In an automobile factory, a 150 lb man who sits and operates a machine (which does the real work) may require no more than 2,500 Cal, while a 175 lb man whose job calls for much walking and some lifting obviously uses much more energy, 3,700 Cal or even more Both men belong to the same union and are classed as factory or industrial workers Furthermore, the way one employs his leisure time affects his total energy need A sedentary worker, such as an office clerk, by working "out-of-hours" at home (carpentry, painting, gardening or going in for some active sport, may raise his energy requirement to that of a man whose working day involves more physical exertion The estimates of energy requirements for various occupations given, in the table on p 62, are only for general guidance Determination of individual energy needs must be based on computation of the time spent in different activities, energy cost of each activity, body weight, etc Examples of how this is worked out for two students are given on p 66

Mental Work

Mental work does not affect the energy requirement appreciably except as it may be accompanied by muscular tenseness Although the metabolism of nervous tissue can be shown to be increased by activity, the amount of energy required is sufficiently small and the proportion of nervous tissue to the total body weight is so low that the influence of its activity is like "a drop in the bucket" Benedict and Benedict,[4] who found that the effort of complicated mental arithmetic increased metabolism 3 to 4 per cent during the short periods it was carried on, compare the relative effects of mental and muscular work as follows, "The professor absorbed in intense mental effort for an hour has an extra demand for food or for calories during the entire hour not greater than the extra need of the maid who dusts off his desk for five minutes"

Growth, Pregnancy, and Lactation

With most adults the desire is to have the fuel intake just about balance the energy requirement so that the weight will be maintained constant. With children, on the other hand, it is important to provide energy *over and above* that required for the internal work of the body and for muscular activity, in order that additional material may be available for increasing the body weight in *growth*. Rapidly growing infants

[4] Benedict, F G, and Benedict, C G, "The Energy Requirement of Intense Mental Effort," Science, 71, 567, 1930

Figure 33 A light-weight, portable respiration apparatus, such as the Douglas Bag is used to determine the energy expended in such active exercise as running. (Courtesy of The New York Times)

Estimations of the total fuel requirements for persons in occupations that involve different degrees of physical activity will be found in the table below. A man whose daily work is chiefly done standing or walking (e g, a carpenter or mason) will require approximately 1¼ times as much energy as one whose occupation is performed sitting (e g, a bookkeeper or machine operator in a factory) A farm laborer will need 1½ times and a ditch-digger or lumberman about 1¾ to 2½ times as much energy as the sedentary worker. This means, of course, that those who perform tasks requiring physical exertion must take more food in order

Daily Energy Requirement According to Occupation

Type of Occupation	*Total Calories per Day* — *Men*	*Women*	*Cal per Kg. per Day*
At rest but sitting most of day	2,000–2,200	1,600–1,800	30–33
Work chiefly done sitting	2,200–2,700	1,900–2,200	34–37
Work chiefly done standing or walking	2,800–3,000	2,300–2,500	38–42
Work developing muscular strength	3,100–3,500	2,600–3,000	43–50
Work requiring very strong muscles	4,000–6,000	—	55–70

Man, 140 lb (— 2 2), 63 6 kg, sedentary (office clerk), 34–37 Cal per kg daily, (63 6 × 34–37) = approx 2,160–2,350 Cal per day

Man, 80 kg (176 lb), active (mason), 43–50 Cal per kg. daily, (80 × 43–50) = approx 3,440–4,000 Cal per day

Woman, 59 kg (130 lb), sedentary (student), 34–37 Cal per kg daily, (59 × 34–37) = approx. 2,000–2,180 Cal. per day

Woman, 68 kg (150 lb), mod active (housewife, farm), 38–42 Cal per kg, (68 × 38–42) = approx 2,500–2,850 Cal per day

The student should notice that, since the calories per kilogram weight are obtained by dividing the *total* need for the day by weight, they *include* needs for basal metabolism and allowance for influence of food.

Table 1. Energy Costs for Different Degrees of Activity per Unit of Body Weight

(EXCLUSIVE OF BASAL METABOLISM AND INFLUENCE OF FOOD)

Activity	*Cal per Kg per Hr*	*Activity*	*Cal per Kg per Hr*
Sleeping	0 09	Exercise, moderate	2 5 avg
Awake, lying still	0 1	Bicycling, mod speed	
Sitting		Carpentry	
At ease		Dancing, waltz	
Reading aloud		Sweeping, vacuum	
Sewing, hand or by motor-driven machine	0 4	Walking, mod speed	
		Exercise, more active	4 0 avg
Writing		Dancing, foxtrot	
Eating		Horseback riding, trot	
Standing, relaxed	0 5	Playing ping pong	
Personal necessities	0 7	Skating	
(dressing, undressing, washing, shaving)		Walking, mod speed	
		Exercise, more severe	6 5 avg
Exercise, very light	1 0	Sawing wood	
Driving automobile		Tennis	
Dishwashing		Horseback riding, gallop	
Ironing (light iron)		Walking up and down stairs	
Typing rapidly		Running	
Exercise, light	1 5 avg	Exercise, very severe	8 5 avg
Office work, sitting		Boxing	
Laundry, light		Rowing, mod speed	
Painting, furniture		Swimming	
Playing piano, moderate speed		Walking, high speed (5 3 miles per hour)	
Sweeping, carpet-sweeper			

Individual

The only way to get a more exact idea of one's individual need for energy is to keep a detailed record of the time spent at different types of activity throughout a representative day and compute the energy used in each activity by means of figures such as are listed in Table 1, above Values for the energy cost of all kinds of specific tasks

have been shown to be storing 12–15 per cent of the energy value of the food taken. This extra energy is stored in the form of newly built tissues As growth rate diminishes, although the total food requirement is more because of the increased size, the allowance needed per unit of body weight becomes smaller. Adults recovering from a wasting illness also require extra energy for building new tissue. In pregnancy there is also need for energy to build new tissue, and in lactation to provide for the energy value of the milk secreted Information concerning the special energy needs of children and pregnant or nursing women will be found in Chapters 24 and 25

ESTIMATION OF ENERGY REQUIREMENTS

General

As stated at the beginning of this chapter, the total allowance for energy requirement must cover amounts needed for three purposes—internal work (basal metabolism), external work, and energy "cost" of the food intake

Basal metabolism determinations on normal adults have shown average values with the following ranges

Men	*Women*
1600–1800 calories daily	1250–1450 calories daily

As stated on p 45, basal metabolism is normally about 1 calorie per hour for each kilogram of body weight and goes on, of course, 24 hours a day. A man of average body build and weight (70 kg. or 154 lb.) will show approximate basal metabolism of $1 \times 24 \times 70$, or 1,680 Cal. If the man's work calls for little physical activity, the total energy required for muscular work may be estimated as about 500 calories daily, or even less. The daily energy requirement for a sedentary man of average weight might be computed roughly thus

	Calories
For basal metabolism	1680
For ordinary muscular activity	500
	2180
To cover the effect of food (10 per cent)	218
TOTAL	*2398*

Another way to get an approximate estimate of caloric requirements is to multiply the weight in kilograms (1 kg $=$ 2 2 lb) by the appropriate figure in the last column of the table on p 62 These figures are obtained by dividing the total need for the day by the number of kilograms of weight, thus giving the caloric need *per day* for each *weight unit* at *varying activity* (sedentary, moderately active, active, etc) For example:

(walking at different speeds, running, sawing wood, dishwashing, typing, etc.) have been determined by numerous research workers, either by direct calorimetry or indirectly by measuring the amount of oxygen consumed over a given time, using various types of apparatus In Table 1, these figures are grouped at certain levels of activity, ranging from sleeping, through sitting tasks, to those that require moderate or more severe physical exertion As the exertion increases, the energy cost (per kg. body weight) increases gradually from about 0 1 Cal. per hour (sleeping) to an average of 8 5 Cal per hour for tasks or sports that involve strenuous muscular activity (swimming, rowing, track events, etc).

In calculating the energy cost of the day's activities, the time accounted for must, of course, add up to 24 hours and the total calories for activity must then be multiplied by the body weight in kilograms (lbs ÷ 2 2) To this total must be added the allowances for basal metabolism (24 hrs.) and influence of food (SDA)

Two examples of such computation of individual energy requirements are given on page 66 Both are for students—one, a young woman most of whose day is spent in sitting occupations (meals, classes, study, movies), the other, a young man whose day is spent fairly similarly except that he takes two hours of moderately strenuous exercise, which markedly increases his calorie requirement Both spend four hours in the classroom, we have assumed that the man drives in a car between home and campus, both walk some about the campus, and that the girl walks to and from her home In spite of similar schedules as students, the energy cost of his activities (nearly 24 Cal per kg) is almost double that of hers (12.8 Cal per kg) In addition, his heavier weight and larger basal metabolism further increase the disparity of their *total* daily energy needs, he will require approximately 3,700 Cal, she only about 2,250 Cal per day

RECOMMENDED ALLOWANCES VS. ACTUAL NEEDS

Within the past decade or more, it has become customary for national and international scientific groups to issue recommended allowances for the various nutrients needed for health, in amounts suited to the requirements of the "average" man or woman, children of different age groups, and pregnant women This has been done (1) to assist in planning food supplies so that there will be enough for all, provided there are funds to purchase an adequate diet, and (2) to educate and encourage people to eat more wisely and so to raise the general level of health, especially in the so-called "backward" or "underdeveloped" countries In the United States, such recommended allowances were first formulated during World War II, by a special committee of the National Research Council, and have since been revised at about five year intervals. The United Nations Food and Agricultural Organization issued its

Table 2. Calculation of Individual Energy Requirements of 2 Students

Young man, mod. active, wt. 70 kg.

	Time	*Energy Cost*	*Total Cal per kg Body Wt*
Sleeping	8 hrs	(.09 × 8)	0.72
Awake, lying still	½ hr	(.10 × ½)	0.05
Dressing, washing, shaving	¾ hr	(.7 × ¾)	0.52
Sitting—eating, reading, televiewing	4 hrs	(.4 × 4)	1.6
Sitting, in class	4 hrs	(.4 × 4)	1.6
Standing, at ease	1 hr	(.5 × 1)	0.5
Driving automobile	1 hr.	(1. × 1)	1.0
Walking, mod. speed	¾ hr	(2.5 × ¾)	1.86
Exercise, light	2 hrs	(1.5 × 2)	3.0
Exercise, active—tennis, or other active sport	2 hrs	(6.5 × 2)	13.0
	24 hrs		23.85

	Cal
Energy needs, young man, *per day*	
Cost of activities (23.85 × 70 kg.)	1,685
Basal metabolism (1C. per kg. per hr.) (1 × 70 × 24)	1,680
	3,365
SDA of food (10% of Cal. above)	336
Total	3,701

Young woman, sedentary, wt. 56 kg.

	Time	*Energy Cost*	*Total Cal. per kg Body Wt*
Sleeping	8 hrs	(.09 × 8)	0.72
Awake, lying still	½ hr	(.10 × ½)	0.05
Dressing, undressing	1⅓ hrs	(.7 × 1⅓)	0.93
Sitting—eating, reading, watching movies	6 hrs	(.4 × 6)	2.4
Sitting, in class	4 hrs	(.4 × 4)	1.6
Standing, at ease	⅔ hr	(.5 × ⅔)	0.33
Walking, mod. speed	1½ hrs	(2.5 × 1½)	3.75
Exercise, light	2 hrs	(1.5 × 2)	3.0
	24 hrs		12.78

	Cal
Energy needs, young woman, *per day*	
Cost of activities (12.78 × 56 kg.)	706
Basal metabolism (1 × 56 × 24)	1,344
	2,050
SDA of food (*10%* of Cal. above)	205
Total	2,255

Table 3. U S. Food and Nutrition Board, Recommended Calorie Allowances, 1958

FOR INDIVIDUALS OF VARIOUS BODY WEIGHTS AND AGES *

Men

Desirable Weight		Calorie Allowances		
Kilograms	Pounds	25 years	45 years	65 years
50	110	2,500	2,350	1,950
55	121	2,700	2,550	2,150
60	132	2,850	2,700	2,250
65	143	3,000	2,800	2,350
70	154	3,200	3,000	2,550
75	165	3,400	3,200	2,700
[illegible]	176	3,550	3,350	2,800
85	187	3,700	3,500	2,900

Women

Desirable Weight		Calorie Allowances		
Kilograms	Pounds	25 years	45 years	65 years
40	[illegible]	1,750	1,650	1,400
45	99	1,900	1,800	1,500
50	110	2,050	1,950	1,600
[illegible]	121	2,200	2,500	1,750
58	128	2,300	2,200	1,800
60	132	2,350	2,200	1,800
[illegible]	143	2,500	2,350	2,000
70	154	2,600	2,450	2,050
75	165	2,750	2,600	2,150

* These allowances assume a mean environmental temperature of 20° C., under normal conditions, adjustments for climatic changes are unnecessary, since most persons are protected from cold by clothes, heating, etc and some are protected from heat by air-conditioning in summer

requirement really should be calculated for each person to achieve any degree of accuracy Within the same age group there will be wide variations of energy needs according to the amount of muscular activity For instance, take two men, both 45 years of age, one a business executive and the other a day laborer The first may consider himself as active, but his activity will be more of the mind than of the muscles, so that he may require only 2,200–2,600 Cal daily The man who works for 8 hours a day at heavy labor will probably require at least 3,500–4,000 Cal

Since physical activity is the most important factor in determining the energy requirement, adjustments need to be made from the "standard" activity assumed in the table above Americans, who ride rather than walk, are inclined to use less energy for physical activity than Europeans. For those who are "sedentary," perhaps about 20 per cent should be deducted from the standard calorie allowances, while for those who are active in sports or do heavy muscular work the calorie allow-

recommendations in 1950, revising them in 1957 (FAO, Nutritional Studies Nos 5 and 15); their allowances for caloric intake for adults are based on an "average" man weighing 65 kg and woman weighing 55 kg., and on a "standard" degree of activity which is assumed to be "fairly active physically, being neither sedentary nor engaged in hard physical labor as a major occupation"

In its revised 1958 recommendations, the U S. Food and Nutrition Board has based its recommendations for adults on a man of 70 kg. (154 lbs.) weight (which is considered to be nearer the American average), and an "average" woman weighing 58 kg. (128 lbs), the degree of physical activity assumed is about that of the U. N. standard, which may be somewhat higher than is common in the United States. Variations of caloric intake suggested for different ages are given for 25, 45, and 65 years, and one may interpolate for ages between these, the age of the average or "reference" man and woman is 25 years The daily allowance for the "reference man" is 3,200 calories and for the "reference woman" is 2,300 calories. Weight is listed as "desirable weight," that is, a suitable or "ideal" weight for the given height, so that persons who are overweight or underweight for height should use the caloric allowance adjusted to the proper weight, rather than for their actual weight

For nutrients other than calories, the U S recommended allowances have been set higher than those for most other countries With plentiful food supplies and the high economic level in this country, higher intakes of protein, minerals, and vitamins are obtainable here than would be practicable to recommend in some other countries, and they are considered conducive to health. Since these allowances are usually about 50 per cent above the actual requirement, it is a gross error to use these recommended allowances as a "yardstick" for adequacy of the diet, i e., to assume that anyone who does not get the full amounts suggested for one or more nutrients is not having his nutritional needs met Individuals vary considerably in the quantities of the various nutrients which they actually require and the standards are purposely set high enough so that even those with the highest requirement will get enough An excess of protein, minerals, or vitamins will do no harm and may promote health. However, even a moderate excess of caloric intake above body needs, if continued, will lead to overweight, which is a health hazard.

In Table 3 will be found the daily caloric allowances for men and women of various body weights and ages, as recommended by the Food and Nutrition Board of the National Research Council in 1958. It should be emphasized that these are estimates, intended for general use and based on the energy needs of so-called "average" men and women. Individuals will vary fairly widely in both basal metabolic needs, and still more in the energy needed for muscular work, so that the energy

total calorie needs per day of each of these individuals (basal metabolism plus allowance for activity, plus allowance for cost of food).

	Sedentary woman, 56 kg wt, Cal	*Sedentary man, 65 kg wt, Cal*	*Muscularly active man, 75 kg wt, Cal.*
Basal metabolism (1 × 24 × wt in kg)			
Allow for muscular activity	500	650	2,300
Allowance for energy cost of food (10% of above sum)	____	____	____
Total daily energy needs			

5 Make a record of your own activities for a sample day, classifying them as nearly as possible under the headings of activities given in Table 1 (p 65) Group the sitting activities, those that involve standing or walking about the room, those that require light or moderate exercise, and select the nearest comparable figure in Table 1 for calories per kilogram of body weight per hour for each Add energy required (per unit of weight) for 24 hours and multiply by your weight in kilograms Calculate your approximate basal metabolism (1 Cal per hr per kg wt), add this to the total required for the day's activities, add 10 per cent of this sum to cover influence of food This gives your approximate energy requirement per day.

6 What is the calorie allowance given in the revised 1958 recommended allowances of the Food and Nutrition Board for your weight (in kg) and the age group nearest your own age (see table on p 69)? Would you classify your degree of physical activity as "sedentary" or "standard"? How does your individual energy requirement, as computed in question 5, compare with the general recommendation for your age, weight, and degree of activity? If your specific requirement differs much from the average, explain what factors cause it to differ (e g, variations from average in size and degree of muscular activity)

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[illegible], 1947

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ance will need to be increased by 20-25 per cent. Thus, the average man of 70 kg. body weight who is sedentary will require only about 2,500 calories, and one of the same weight (and age) who takes much muscular exercise will need 3,900 calories, or more. The Food and Nutrition Board itself recommended a simple way to arrive at a rough estimate of individual caloric needs by the statement (1953) that "the proper caloric allowance for an individual is that which over an extended period will maintain body weight . . . at the level most conducive to well-being."

QUESTIONS AND PROBLEMS

1 Name the three categories of energy needs that together make up the *total* energy requirement of a normal adult Why is it necessary to allow extra energy to cover the effects of food? What factor has by far the greatest effect quantitatively in raising energy expenditure above the level of basal metabolism? Why does mental work have such an insignificant effect on the total energy expended? Under what special circumstances will an adult need an extra allowance of energy for building new tissues?

2 The amount of energy required for muscular work is proportional to the amount and severity of the work done, as illustrated by the following problem: If a man lying quietly requires 77 calories per hour and his energy need sitting in a chair is 30 per cent higher, how much energy per hour will he need sitting at rest? If typewriting rapidly increases the energy need by 82 per cent over that lying down, how many calories will he use per hour sitting and typing?

3 Violent muscular exertion causes a great rise in energy expenditure over that at the resting level, but when continued for only a short time it does not markedly increase the total day's energy requirements, as illustrated by the following problem: Suppose that a man is sitting in the station quietly, he suddenly realizes his train is about to leave and makes a run for it, after the run that lasted two minutes, he relaxes in a seat on the train If he uses 100 Cal. per hour sitting as rest, and 570 Cal. per hour while making his dash for the train, how many calories would he use in the 2 minute run? Would his energy metabolism return at once to 100 Cal per hour when he took his seat on the train, and if not, why not?

4 Assume that each of the following persons has a basal metabolism of 1 calorie per kilogram per hour—a woman who weighs 56 kg. (123 lb.), a man who weighs 65 kg (143 lb.), and a man who weighs 75 kg (165 lb.). Assume that the woman needs 500 Cal to cover her muscular activity, the first man needs 650 Cal, and the second man needs 2,300 Cal for the same purpose (since he does 8 hours of muscular work). Assume that each needs 10 per cent of the total calories used in basal metabolism plus muscular activity added to cover the effect of food Calculate the

Fuel Value of Foods and Control of Body Weight

THE DISCUSSION in this chapter is designed to answer three questions of considerable importance, namely

(1) How does the body transform fuel foodstuffs so as to set free energy for its use?

(2) How may the fuel value of foods be determined or estimated?

(3) How can the fuel intake be adjusted to the energy needs so that the body will be in "energy balance" and maintain constant weight?

ENERGY FOR WORK FROM BURNING BODY FUELS

The body gets energy for its internal and external work in a manner similar to that in which an internal combustion engine sets free energy from fuel. In an automobile engine, gasoline vapor is mixed with air, ignited by a spark, and burned (oxidized) with a resultant release

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Many careful experiments on human beings in the respiration calorimeter have shown that the amount of energy that appears as work and heat is exactly equal to the energy value of the fuel burned and oxygen consumed, thus proving that the *law of the conservation of energy* holds true for the human body This means that all energy used in the body must come from the burning of fuel foods or of body tissues, and that all energy supplied in food is sooner or later recovered in some form If a person eats an insufficient amount of fuel foods to cover the cost of energy expended, he will be forced to burn up some of his body tissues and will lose weight, since the body cannot create energy out of nothing. On the other hand, if his intake of fuel foods is in excess of his energy needs, the extra energy will be stored in the form of tissues (usually fat) and he will gain weight Remember, the next time someone tells you that he gets along on a remarkably small amount of food and still gains in weight, that he is asking you to believe the impossible because all energy used or stored *must* be derived from a corresponding energy intake in the form of foods

Differences between the Body and a Machine

The analogy between the body and the combustion engine, although very striking in its main essentials, cannot be pushed too far In a number of respects the living organism differs radically from the non-vital machine, and in practically all instances these differences represent advantages to the body in adjusting to its environment and varied needs It has been pointed out previously that the three fuel foodstuffs can be used (within limits) interchangeably as fuel, whereas the gasoline engine can use only one kind of fuel Other important dissimilarities between the man-made machine and the human body in their use of fuel and transformations of energy are summarized and contrasted in Table 4 (p 76)

The fact that the *internal work of the body* goes on twenty-four hours of the day and is absolutely essential to keeping up the life processes has already been emphasized in the discussion on the energy needs of the body (p 42), so that it is unnecessary here to do more than point out that this condition is in direct contrast with the machine, which needs no energy at all to maintain it while idle. In fact, the machine needs practically no material for repair. All it seems to need is lubricating oil to keep it in smooth running order and fuel while it is doing work. These are analogous to those substances in the food which serve to regulate body processes (water, mineral salts, and vitamins[1]) and the fuel foods used for external work in the body In addition, the body needs material for repairing wear and tear on its tissues, and for the continuous up-keep of the vital internal activities for which there is no counterpart in the machine.

of energy in the form of work and heat. In the body, the three fuel foodstuffs (carbohydrates, fats, and proteins) are oxidized in the tissues, by means of oxygen brought to the tissues by the blood, and energy is liberated as heat and work. The energy set free as a result of oxidation was stored up in the fuel in both cases in the form of chemical energy, with some also from chemical energy in the oxygen which is always required for any combustion. During the process of combustion, carbon and hydrogen in the fuel or foodstuff are oxidized to carbon dioxide and water, products that contain less chemical energy than the substances which gave rise to them Since no energy is ever created or lost, the extra energy appears as heat and work. We may represent the transformations of energy that occur when food or fuel is burned by the following equation·

$$\begin{bmatrix}\text{Chemical energy}\\ \text{in food or fuel}\end{bmatrix} + \begin{bmatrix}\text{chemical energy}\\ \text{in oxygen used}\end{bmatrix} = \begin{bmatrix}\text{chemical energy}\\ \text{in products formed}\end{bmatrix} + (\text{heat})$$
$$+ \begin{bmatrix}\text{mechanical energy}\\ \text{used for work}\end{bmatrix}$$

Similarity of Body to a Machine

From the foregoing discussion it is apparent that the body is strikingly like a combustion engine in several important respects:

(1) Energy for work is released by *oxidation* or burning of fuel.
(2) *Heat* is a *by-product* of the transformations by which energy is released.
(3) Both conform to the *law of the conservation of energy.*

Fuel is oxidized in both the body and the machine primarily for the purpose of setting free *mechanical energy* to be utilized in doing work However, in both cases. more of the energy set free is in the form of *heat* than of mechanical energy The relative proportion of fuel energy that is converted into mechanical energy is called the *mechanical efficiency* of only about 10 per cent of its in of cars, whereas the mech is 20 per cent and that of a Diesel engine is nearly 40 per cent The average mechanical efficiency of the body may be said to be about 20 per cent, approximately that of a good automobile engine. This means that to do a given amount of work about five times as much body fuel must be oxidized as would be represented by the work alone, since only about ⅕ of the energy of the fuel is transformed into work energy while about ⅘ of it appears as heat It is no wonder that we experience the feeling of heat while doing strenuous work and that even the internal work of the body (basal metabolism) generates enough heat so that temperature regulation of the body (p 50) is called into play.

liver and muscles. This it uses for its "hand-to-mouth" supply of fuel, keeping the stores of fat as a reserve "fuel tank" to be drawn on only if there is a lack of ready fuel Although the body possesses little ability to store extra protein, the muscle tissues are rich in protein, some of which can be used for fuel if necessary As they form part of the most vital structures of the body, protein tissues are not drawn on for energy except in time of extreme need With continued lack of food the body burns up its reserve fuel in the following order first the limited amount of carbohydrate stored (glycogen), then the fatty tissues, and finally the protein tissues Thus under ordinary conditions of living we have a wide margin of safety as to fuel stored in the body

In that physiological mechanism by which the muscle is prepared beforehand for the almost instantaneous mobilization of energy upon demand, and by which most of the real oxidation occurs in the process

Figure 34 Comparison of energy charge in muscle before and recharging after action with action of a rubber band sling gun (energy charge in stretched rubber band, released to propel stone, and recharged by returning to stretched position)

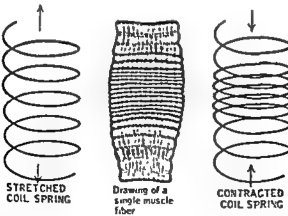

Figure 35 Comparison of muscle fiber to a coil spring Note the cross striations in the muscle fiber, which can be drawn closer together as the muscle contracts and are further apart as it relaxes

Table 4. Comparison of Body and Machine in Use of Fuel

Body	*Machine*
1 Energy consumption never stops	1. Need for energy stops as soon as machine ceases external work.
2 Can store surplus energy.	2 and 3 Machine has no ability to store fuel or to run on borrowed energy
3 Can borrow from stored energy	
4 Energy released in muscular contractions is present all ready to be touched off, like that in a wound-up spring or charged electric battery	4 and 5 Combustion engine has no ability to be charged ahead of time in readiness for action, nor does recovery from action take place after work has ceased.
5 Considerable oxidation takes place after the work is over, in order to prepare the muscle for next contraction—similar to rewinding the spring or recharging an electric battery	
6 Muscle can (a) adapt the effort to the amount of the load (b) vary in mechanical efficiency under different circumstances	6 An engine ordinarily does not possess either of these abilities.
7 Body shows some loss of fuel through inability to completely digest and absorb food or to completely oxidize it in the tissues	7 All of the fuel gets into the engine and should be completely oxidized, if ideal conditions prevail

Moreover, we all know that the life processes would not stop, nor would one even need to discontinue external work, if he stopped eating for a few days. *It would certainly be more than inconvenient if the body* had no ability to *store energy* and to draw in time of need on these energy stores in its tissues, but were obliged to come to a dead halt whenever the supply of fuel from without was withdrawn, just as the automobile engine does when the gasoline gives out Fortunately, we possess a safety device which renders it almost impossible for the body to run out of fuel Whenever there is a greater amount of energy in the food intake than is required to supply the current needs of the body, most of this excess energy is saved and stored up in the tissues

The form in which extra fuel is usually stored in animals is in fatty tissue, and the body can work over an excess of carbohydrates and proteins in the diet and build them into fats for storage, as well as store directly any fats not needed at the time The body can store only a very limited amount of carbohydrate as "animal starch," or glycogen, in the

fuel and oxygen are needed to produce a given amount of work, while a larger proportion of the energy appears as heat under these conditions

During World War II a great deal of research was devoted to determining whether the diet and physical status of men could be a major influence in conditioning them for superior physical performance and warding off fatigue The results were largely negative, no special type of diet seemed to promote vigor and combat fatigue better than a good mixed diet that met all body needs However, in preflight meals for aviators flying at high altitudes, endurance was better after a meal rich in carbohydrates than after one rich in protein After prolonged periods of low calorie intake (semi-starvation), there was lessened efficiency in performing muscular work and various personality changes Of course, a good general diet that supplies plenty of calories, and training that accustoms the muscles to work does make for increased muscular efficiency. The physical condition of workers and the working conditions in a factory can have a definite influence on the industrial output

Even with the best mechanical efficiency, sufficient energy is necessarily diverted into *heat* to be more than enough under usual conditions to heat the body to the tropical temperature maintained in the tissues, so that the problem of heat regulation is generally one of getting rid of excess heat Everyone is familiar with the glow of extra heat produced by vigorous exercise, and heat in smaller amounts is a constant by-product of any action that involves work

ENERGY VALUE OF FOODS

How Fuel Value of Foods Is Determined

The fuel value of foods depends primarily upon their chemical composition, i e, upon the relative amounts of the three fuel foodstuffs (carbohydrates, fats, and proteins) that they contain It may be determined by either of the following methods.

(1) direct determination in a calorimeter, or
(2) calculation from its content of the three fuel foodstuffs

The fuel value of a pure foodstuff or a natural food may be determined by direct calorimetry, i e, by complete oxidation in a calorimeter like the one shown in Figure 37, where the calories released are computed from the rise in temperature of a known volume of water It may also be determined by indirect calorimetry, i e, by measuring the amount of oxygen used in burning a weighed sample and calculating the number of calories that burning with this quantity of oxygen would release (calorie equivalent of given volume of oxygen) This can be accomplished in a simpler apparatus called the oxy-calorimeter These two methods are analogous to direct calorimetry for measurement of heat

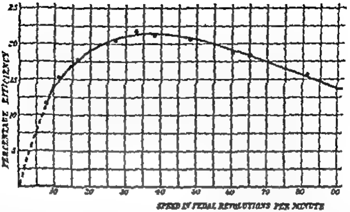

Figure 36. Graph showing relative mechanical efficiency of a cyclist at different speeds of pedaling. Efficiency is greatest at moderate speed, work being less efficiently done when pedaling is either very slow or very fast. (*Constructed from data obtained by Sylvia Dickenson. Journal of Physiology.*)

of recovery or *recharging of the muscle* for subsequent action, we have another point of superiority of the animal body over the machine. The energy for work is set free by oxidations in the muscles, as a result of which lactic acid is formed. An athlete may make a sudden and violent spurt, using all available oxygen in the tissues to oxidize part of the lactic acid produced by the exercise. As little as one fifth of the lactic acid formed may undergo complete oxidation to supply energy, the remainder being rebuilt to glycogen and stored as reserve fuel in muscles and liver. Oxidations incidental to ridding tissues of waste products and rebuilding glycogen stores may go on for some time after exercise is over (up to 70 minutes after severe muscular exertion). The oxygen required for this purpose is called the "oxygen debt" incurred by the muscle tissue during exercise. Muscles are more or less elastic and perform work through alternate contraction and relaxation, the cross striations (characteristic of voluntary muscles) being drawn closer together as the muscle contracts (Fig. 35, p. 77).

The *mechanical efficiency of the body* varies considerably. It is influenced by several factors not operative in the machine, such as the type of work performed, previous training or practice, fatigue, the amount of the load, and the speed and conditions under which the work is done. When the body is in good muscle tone and accustomed to the task (e.g., in trained bicycle riders), efficiencies as high as 33 per cent have been obtained. Under unfavorable conditions, such as an unaccustomed task, too heavy a load, too high rate of speed, *inconvenient posture* for the task, or fatigue (even before it becomes conscious), the mechanical efficiency may fall as low as 10 per cent. Low mechanical efficiency means that work is accomplished at a greater cost, i.e., more

fuel and oxygen are needed to produce a given amount of work, while a larger proportion of the energy appears as heat under these conditions

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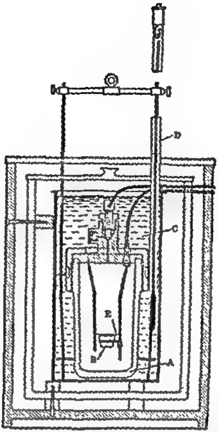


Figure 37 Cross-section diagram of the bomb calorimeter used for determination of the fuel value of foods A weighed sample of the food is placed in the dish *B* in the inner chamber, which is charged with oxygen and sealed tight, the burning is set off by an electric spark (passed between the wires) and the heat liberated is measured by the rise in temperature of a known volume of the surrounding water, the outer sections are for insulation to prevent loss of heat to exterior (Courtesy of Emerson Apparatus Co, Boston, Mass)

given off by man and indirect calorimetry by means of the respiration apparatus

The average heats of combustion of the *pure foodstuffs*, determined by numerous experiments, were found to be as follows

Carbohydrate	4 1 Calories per gram
Fat	9 45 Calories per gram
Protein	5 65 Calories per gram

Fats have a higher fuel value because their molecules contain such large amounts of carbon and hydrogen, along with relatively little oxygen, much extra oxygen is required for their burning, so much heat is released Carbohydrates have enough oxygen in their molecules to com-

bine with all of the hydrogen, so only enough oxygen is required for burning to combine with the carbon and less than half as much heat is liberated Proteins are intermediate between fats and carbohydrates in fuel value, when they are completely oxidized in the calorimeter

Calculating the Fuel Value of Foods

This may be done by multiplying the number of grams of each fuel foodstuff in a given quantity of the food by the fuel values per gram of carbohydrate, fat, and protein But the fuel values which the body can derive from these substances are not identical with those obtained when they are completely oxidized in the calorimeter There is a small loss entailed due to incomplete digestion and absorption from the intestine A further deduction must be made in the case of proteins, because these substances are not as completely oxidized in the body as in the bomb calorimeter, the nitrogen-containing products excreted in the urine represent latent heat that amounts, on the average, to 1 3 calories for each gram of protein burned in the body When the necessary corrections for these factors are made, the *physiological fuel values* per gram for the three fuel foodstuffs are as follows

	Bomb calorimeter value, Cal	*Physiological fuel value, Cal*
Carbohydrate,	4 1 − 2% loss in digestion = 4 01	4 0
Fat	9 45 − 5% loss in digestion = 8 977	9 0
Protein	5 [illegible] − 1 3 C loss in urinary end products = 4 35	
	− 8% loss in digestion =	4 0

The above general factors—4, 9, 4 calories per gram for protein, fat, and carbohydrate, respectively—have served for nearly 50 years in estimating the fuel value of any food whose composition is known For example, the fuel value of milk is calculated as follows

Milk contains 4 9 gm carbohydrate, 3 5 gm protein, and 3 9 gm fat for every 100 gm

Each gram of carbohydrate and of protein has a fuel value of 4 calories, and each gram of fat furnishes 9 calories

100 grams of milk will have a fuel value of

(carbohydrate)	4 9 × 4 =	19 6
(protein)	3 5 × 4 =	14 0
(fat)	3 9 × 9 =	35 1
(total)		68 7 calories

A glassful of milk (8 oz) weighs 240 grams, and hence has a caloric value of 68 7 × 2 4, or 165 calories

During World War II, various "more specific factors" were proposed for calculating the caloric values of foods and the energy values of foods listed in the most recent tables of food composition issued by the govern-

Table 5. 100 Calorie Portions of Some Foods

Food	*Quantity*
High fuel value	
Chocolate creams	2 medium-sized
Brazil nuts	2 " "
Figs	1½–2
Dates	3–4
Cheese, American	1⅛ in. cube
Peanut butter	1 tbsp.
Any clear fat (or mayonnaise)	1 tbsp
Cream, thick or whipped	[illegible] tbsp.
Intermediate	
Eggs	1⅓ medium
Lean meat, cooked, medium done	2 ounces (lean portion [illegible] small lamb chops)
Bread	approx 1⅓ avg slices
Breakfast cereal, cooked	⅔–¾ cup
Potato, white, baked	1 medium-sized
Low fuel value	
Grapefruit	1 medium
Peaches, fresh	2 large
Tomatoes	4 medium
Cantaloupe	1 melon, 5 in diam
Asparagus	20 large stalks
Celery	20 " "
Cabbage, shredded	3½–4 cups
Lettuce	2 large, firm heads (Iceberg)

ment[2] are based on these more specific but more complicated factors For the chief foods in the American diet, differences between the two methods of calculating are not large Comparison of the values for white and whole wheat breads obtained by the two sets of factors are given below as an example.

	Calories per 100 gm	
	Gen factors	*Spec factors*
Bread, white, enriched	270	275
Bread, whole wheat	257	240

Foods of High and Low Fuel Value

Foods *vary widely in their energy value.* Some are such concentrated fuel that it takes only a small bulk of them to yield a considerable amount of energy, or a large number of calories. Others contain so much of non-energy–producing substances, such as water and cellulose (fiber) and have so low a content of the fuel foodstuffs that they yield only a small number of calories for a comparatively large bulk of food.

In general, the foods with *high fuel value* will be found to be those that are either *rich in fat or low in water* content. Thus all the fatty

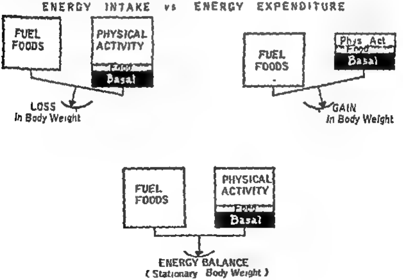
[2] Composition of Foods, U S Dept Agric, Agriculture Handbook, No 8, June, 1950 The specific factors are based on relative digestion and absorption of individual foods

foods will be relatively high in calorie value, as will also foods low in moisture content such as cheese, nuts, dried legumes, dried fruits, and the like

Foods of low fuel value will include most fresh fruits and vegetables, especially green leafy vegetables, since these foods have a high content of both water and cellulose Lean meats, cereal foods, and starchy vegetables are intermediate in fuel value between foods that are classed as high or low in energy value

The *100 calorie portions* of different foods have been much used as an aid in visualizing and remembering which foods are high or low in fuel value. It takes only a *small bulk* of a high calorie food to furnish 100 calories, while a relatively large mass of low calorie food must be taken to give the same calorie value, as should be readily apparent from Table 5 (p. 82)

More exact tables of the energy value of foods are required for a fairly accurate check on the number of calories furnished by a day's diet The fuel values of *average servings* of the more common foods will be found in the table on Nutritive Values of Foods, to be found in the Appendix on pages 568 to 581



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WEIGHT CONTROL

Stationary Weight an Index of Energy Balance

Although it is sometimes of interest to make a check on about how many calories one is taking daily, this is usually not necessary because body weight constitutes an unerring index of whether the food is furnishing energy equal to, in excess of, or below the energy requirements of the body When energy intake just about balances outgo, the body neither gains nor loses in weight Minor weight variations (1–2 lb) from day to day are of little significance and often may be due to fluctuations in water content of the body But if the body weight keeps about the same over a considerable period of time, we can know that the fuel value of the food intake is adjusted so that it is practically equal to the energy requirements

After an adult has attained full growth, it is advantageous to maintain body weight at about a certain norm for the height, either overweight or underweight represents disadvantages which usually make for lesser efficiency or poorer health Insurance companies and health officials now urge people to attempt to maintain in later life the weight which is normal at 25 or 30 years of age Table 6 shows the ideal weights for height for men and women, according to recent figures of the American Medical Association, irrespective of age but varied for three types of body build. A wider range of variations for different body builds and more detailed height figures are to be found in the table on page 529 Students under 20 years of age will find their normal weight for height in tables in the Appendix, pages 590 to 593

Table 6. Theoretical Normal or Ideal Weights*

For Men and Women of Different Body Builds
Weight in Pounds

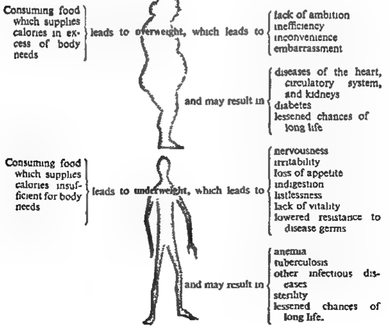
Height (Without Shoes)	*Small Frame*		*Medium Frame*		*Large Frame*	
	Men	*Women*	*Men*	*Women*	*Men*	*Women*
4′ 9″		107		114		122
4′ 11″		110		118		126
5′ 1″	120	117	128	124	136	132
5′ 3″	127	123	135	131	143	139
5′ 5″	134	131	142	139	151	148
5′ 7″	141	138	150	146	159	155
5′ 9″	149	144	158	153	168	162
5′ 11″	158		167		177	
6′ 1″	169		178		187	

* From "How to Weigh Less," Council on Food and Nutrition, American Medical Association, 1959

Surplus of Calories

If the body weight is persistently, even though slowly, increasing, there is certainty that the fuel value of the food intake is greater than the energy needs of the body Even so small an excess as 200 calories per day (equivalent to 2½ pats of butter or 4 chocolate creams), if persistently indulged in, will mean the storage of 17 pounds of body fat in a year's time Usually overeating as to calories is the result of too great fondness for foods of high fuel value (fatty foods, starchy foods, and sweets), but decreased muscular activity (less energy used for external work) is often a contributing factor As one becomes older, there is a tendency for both the basal metabolism (energy for internal work) and physical activity to be lessened If one carries over into later life the food habits of younger years, the weight is almost certain to increase undesirably, it will be necessary to take either less food or more exercise, or both, in order to keep the weight down to about the normal for age 30 Those who have already acquired considerable superfluous flesh will have to practice even greater self-denial in curtailing their caloric intake in order to lose weight and bring weight back to normal for their height A decrease in food intake of 500 calories daily below the

Disadvantages of Overeating or Undereating as to Calories



amount that would presumably keep body weight constant will normally result in the "burning-off" of fatty tissues in the body to an extent that will reduce body weight about one pound per week; reduction of fuel intake by 1000 calories per day below level required for maintenance should cause a weight reduction of approximately two pounds weekly, which is about as rapid weight reduction as is considered advisable. The inconveniences and health hazards of carrying weight much in excess of normal are enumerated in the outline on page 85 and are also discussed in Chapter 27 (pp 531–532).

Shortage of Calories

Appetite is more likely to cause people to overeat than to take too low an amount of fuel foods to meet their energy needs However, some persons are inclined to leanness, have a poor appetite, or have acquired poor habits of eating or faulty health habits that lead to undernutrition. They may accept this condition as normal, protest that they feel all right, and experience difficulty in taking larger amounts of food. But living on too low a nutritional level, of which underweight is one index, carries its own disadvantages Such a person tires easily, is liable to nervousness and indigestion, and is more susceptible to infections than one who is more adequately nourished Tuberculosis is one of the hazards of underweight, especially in younger adults More rest coupled with increased food intake, especially of foods that provide calories in concentrated form, will lead to increases in weight, which are usually accompanied by surprising increases in general vitality and well-being For younger adults, a moderate amount of extra weight is good health insurance, after 40, a moderate amount of leanness tends to promote length of life, according to the insurance companies [4] Persons who are more than 5–10 per cent under normal weight for their height will do well to examine their dietary and general health habits and to make a determined effort to bring their weight more nearly up to normal by taking additional fuel foods.

Varying the Fuel Value of the Diet

Because the body can store excess calories and draw on its fuel reserves of fatty tissue in time of need, the fuel value of the diet may be varied, at least for shorter periods, without harm and in a wider range than that of any other nutritive essential It should not be forgotten that the need for such other nutritive essentials as proteins, minerals, and vitamins is constant and should be met by the food intake at whatever level of calorie intake is adopted for purposes of losing or gaining weight For this reason, the diet should be built around certain "basic" foods

[4] Underweight is, of course, especially dangerous for children, since they need extra calories for growth Low caloric intake is often associated with insufficiency of one or more other essentials for growth (proteins, minerals, and vitamins) The special needs during the growth period will be discussed elsewhere (pp 494 to 497).

that provide these nutritive essentials—protein-rich foods such as meat and eggs, with milk, fruits, and vegetables to provide minerals and vitamins Then we may safely add or subtract calories according to current demands or desires

Fortunately there are certain foods that furnish chiefly calories and little of the other nutritive essentials Sugar and pure fats contribute only energy in the diet, so that varying the amount of these foods taken is the easiest way to alter the caloric intake without affecting the other nutritive values of the diet Other foods that are useful mainly for their energy value and carry only minor amounts of other nutrients are sweets (candy, jams, jellies, sweet desserts), most starchy foods (breads, breakfast cereals, cereal puddings), and fatty foods (fat meats, salad dressings, chocolate, cream, rich desserts, etc) To illustrate how markedly the intake of calories may be influenced by omitting or adding various portions of such foods, the caloric values of some common food combinations are listed here.

1 avg serving rich and/or sweet dessert	200–400 calories
1 avg serving cereal, 2 oz cream, 2 tbsp sugar	325 calories
1 tbsp mayonnaise dressing and 2 tbsp jam	200 calories
2 slices bread and 2 pats butter	270 calories
1 medium potato and 1 pat butter	170 calories

Another way to cut down on calories is to eat foods in their natural state, unadulterated by added calories in the form of sugar or fat A medium-sized raw apple furnishes 76 Cal, a baked apple 213 Cal, and a piece of apple pie about 377 Cal Substituting a pint of skim milk for an equal amount of whole milk will cut down the caloric intake by about 160 Cal

Examples of menus at three different caloric levels will be found at the top of page 88 The 2200 Cal diet represents approximately the level for maintaining body weight for a small, sedentary man or a woman who is moderately active physically, the 3000 Cal diet should suffice for a moderately active man or, for others of lesser energy needs, may be used to gain weight, the 1200 Cal level represents a diet for losing weight The student should study these parallel menus in order to note (1) that all of them contain the "basic" foods necessary to furnish nutritive essentials other than energy, (2) that for the most part the same foods form the basis of the menus, with variations in quantity served or substitution of a *similar food of higher or lower fuel value*, and (3) that the more radical variations in caloric intake are effected by omitting or adding more of fatty foods, sugar, and starchy foods—foods whose chief contribution to the diet is their energy value.

Perhaps the main lesson to be learned from this section is that weight control, although important to health, is an easy matter if taken in time The omission or addition of one slice of bread and a couple of pats of butter daily may be all that is required to balance energy intake with

Menus at Different Caloric Levels

1200 *Calories, Reducing* (*approx.*)	2200 *Calories* (*approx.*)	3000 *Calories* (*approx.*)
Breakfast Tomato juice, 6 oz 1 boiled egg 2 slices melba toast Coffee with ½ cup hot milk	**Breakfast** Orange juice, 6 oz Toast, 2 slices (½ in thick) Jam, 1 tbsp Coffee with 3 tbsp. thin cream	**Breakfast** Orange juice, 8 oz Cereal, cooked, ⅔–¾ cup Milk, ½ cup 1 boiled egg 3 strips crisp bacon Toast, 1 slice Coffee Cream, thick, 3 tbsp.
Lunch Clear soup, 1 cup 2 slices canned tongue Green salad, with 1 tbsp. lemon jc. or vinegar Cottage cheese, 2 tbsp Ry-krisp, 2 double squares, or 3 sq. graham crackers Milk, skim, 6 oz (small glass)	**Lunch** Clear soup, 1 cup Saltines, 2 2 egg omelet Green salad, with 1 tbsp French dressing Bread, 1 slice Milk, whole, full glass (8 oz.)	**Lunch** Cream soup, ¾ cup Saltines, 2 3 slices canned tongue Green salad, with 1 tbsp French dressing Bread, 1 slice Baked apple, 1 large Tea
Dinner Ground beef, round, sm. patty Carrots, med. serving Peas, green, ½ cup Bread, 1 slice ½ cantaloupe or small raw apple Milk, skim, 6 oz.	**Dinner** Roast leg of lamb, 2 slices (75 gm.) Potato, 1 medium Carrots, med. svg. Peas, green, ½ cup Bread, 1 slice Cup custard, 1 Cookies, sugar, 2	**Dinner** Roast leg of lamb, 2 slices (75 gm.) Potato, 1 medium Carrots, med. svg. Peas, green, ½ cup Bread, 1 slice Pie, piece, ⅙ of pie Milk, whole, 8 oz. glass
Day's allowance of: Sugar, 2 tsp Clear fat, 1½ tbsp	 Sugar, 3½ tbsp Clear fat, 2½ tbsp	 Sugar, 3½ tbsp Clear fat, 4½ tbsp

energy expenditure, the substitution of fresh fruit in place of desserts of high fuel value, or the omission of dessert, may accomplish the same end, provided one follows the new regime consistently. Watch your weight from week to week, or month to month, and promptly make the small adjustments in intake of fuel foods as required to prevent undue loss or gain in body weight. It is far easier and better to secure a balance between fuel intake and fuel needs as you go along than to make the more drastic changes in diet later that will be needed if undernutrition or excessive weight gains have been allowed to occur.

QUESTIONS AND PROBLEMS

1. What classes of food substances can be burned in body tissues as fuel to set free energy? Since burning is a process of oxidation, what other substance is required for setting free energy from body fuel? How is oxygen for this purpose brought to the tissues? Write the equation (see p. 74) that represents the energy transformations that take place

in the body when body fuel is oxidized Why must the amount of energy be the same before and after such a transformation?

2 How does the body resemble and how does it differ from a machine in its use of fuel to set free energy?

3 What is meant by the mechanical efficiency of muscular work? If a man did work that had a heat equivalent of 550 calories and used fuel equivalent to 2750 calories in the task, he would show a mechanical efficiency of 20 per cent (500 ÷ 2750 × 100), which is about normal How many calories of fuel would another man require to perform the same work if his mechanical efficiency were only 10 per cent? What conditions make for poor mechanical efficiency, for good mechanical efficiency? In what form does the energy that is set free from body fuel but not transformed into work energy appear? Why does one feel hot after muscular work? Why does the heart beat faster and breathing become more rapid?

4 How may the fuel value of foods be determined? Why is the physiological fuel value of the foodstuffs somewhat less than their fuel value as determined in the bomb calorimeter?

5 Give the calorie value *per gram* of pure protein, carbohydrate, and fat when used as body fuel Calculate the fuel value of 100 grams of each of the foods whose composition is given below (by multiplying the grams of protein, fat, and carbohydrate each by the proper caloric value per gram, and adding these figures)

	Protein, gm	*Fat, gm*	*Carbohydrate, gm*
100 grams of white bread contains	8 5	3 2	51 8
100 grams of butter contains	0 6	81 0	0 4
100 grams of raw cabbage contains	1 4	0 2	5 3

6 What types of food are high in fuel value? low in fuel value? Make a list of foods of relatively high fuel value, which may be used liberally in high calorie diets but included in scanty amounts in low calorie diets Make a list of foods that are low enough in fuel value so that they can be included in liberal amounts in low calorie diets

7 Estimate the fuel value of the two breakfasts given below, using the calorie values for the different foods as given in the table of Nutritive Values of Foods in Average Servings or Common Measures in the Appendix (pp 568–581).

Breakfast 1	*Calories*
Orange juice, small glass (6 oz)	
Bread, 2 slices, toasted	
Butter, 1 average square	
Jam, 1 tbsp	
Coffee, with 1 tbsp thick cream	
Total	

Breakfast 2	*Calories*
Orange juice, fresh, large glass (8 oz)	
Cream of wheat, cooked, 1½ cups	
Thin cream, ¾ cup (6 oz)	
Bread, toasted, 2 avg slices	
Butter, 2 avg squares	
Coffee, with 2 tbsp thick cream	
Sugar, 5 tsp (slightly rounded, or 2 tbsp)	
Total	

8 Make a record of your food intake for one day (including all food taken between meals). Using the table in the Appendix for calorie values of common foods in average servings or common measures, calculate your calorie intake for one day. How does it compare with your energy requirement? Would you expect to gain or lose weight, or to maintain present weight under these conditions? What is your ideal weight for height (consult table on p. 84)? What are the disadvantages of overweight? of underweight?

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The Protein Requirement

In addition to meeting the energy requirement of the body, food should also supply amounts of the various *building materials* sufficient for body needs. Chief among the materials needed to build tissues is *protein*. Since protein is a vital part of the nucleus and protoplasm of every cell, some of it is found in all of the body tissues. The outer layers of skin, the hair, and nails consist almost entirely of an insoluble protein called keratin, whereas fatty tissue has a very low content of protein. The most active and abundant tissues of the body, the muscles and glandular organs, are high in protein. Muscles contain about 70 per cent of water but, [illegible]

[illegible] proteins in solution in its fluid portion, or plasma.

We have already learned something of the chemical nature of proteins (pp. 32–34), that they are the only foodstuff that provides nitrogen in utilizable forms, that they are made by the linkage of many different amino acids, and that their "biological value" is dependent upon the as-

sortment of amino acids which they furnish In this chapter we will consider further the various *uses* for protein in the body, the factors that determine *how much protein is needed,* and the *recommended level* of protein intake, including both the *quantity* and *quality* of the protein in the diet.

Functions of Protein in the Body

The principal uses for protein in the body are

(1) For *building new tissues* in { growth (childhood), pregnancy and lactation, building up adult after wasting illness, or in athletic training,

(2) For *upkeep of tissues* already built,

(3) For *energy,*

(4) As a regulatory substance,

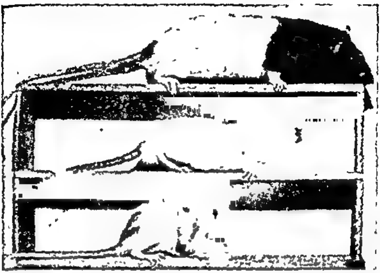
(5) As a precursor for enzymes, hormones, antibodies, etc.

1. Since protein is vital to and omnipresent in body tissues, it should be self-evident that it must be supplied in the diet for the *building of new tissues.* "Protein is man's chief source of nitrogen, and the rate of supply obviously conditions growth, maintenance, repair, reproduction and lactation To subserve these processes is its primary function "[1]

The *amount* needed for these purposes naturally depends on the extent or rapidity of these processes For instance, in the rapidly growing infant as much as one third of the protein of the food may be retained for building new tissue As growth becomes less rapid, the percentage of the protein intake retained in the body for tissue building will be less, but a plentiful supply of high quality protein is necessary throughout the growth period in order to secure the best possible growth and development In the later months of pregnancy and in lactation, an extra quota of protein is also needed. Likewise, an athlete in training may require some extra protein for building muscle tissue, as his muscles strengthen and enlarge as a result of exercise

When there has been excessive breaking down of the tissues, as in starvation or wasting illnesses, there will be a need for extra protein for tissue repair or rebuilding This has long been realized in the diets given to build up patients after prolonged fevers or those who are chronically undernourished In recent pitiful cases of half-starved persons, those rescued from prison camps or civilians in war-ravaged lands, predigested proteins were given at first, followed by mixtures of dried eggs and milk (foods rich in high quality proteins)

[1] Cuthbertson, D P, "Quality and Quantity of Protein in Relation to Health and Disease," Nutr Abst & Rev, 10, 1 1940



of protein supplied in the case of the two lower rats. (Courtesy of Dr J. C. Coffin, New York City)

Recently emphasis has been placed on the fact that excessive destruction of body protein occurs in various periods of "stress and strain," in addition to infectious diseases (fevers). Obviously, after severe hemorrhages extra protein will be needed for regeneration of hemoglobin and other blood proteins, also after extensive burns there is "toxic destruction" of protein, as well as need for protein to rebuild damaged skin and muscle tissues. Cuthbertson[2] found that a slow but prolonged loss of nitrogen from extra metabolism of body protein followed bone fractures, and a similar but brief undue protein loss occurs even after simple surgical operations. Selye,[3] in his book on "Stress," explains this undesirable reaction of the body to tissue damage (trauma) by the theory that increased breakdown of body protein is caused by increased output of hormones from the pituitary and adrenal glands. In all of the above conditions, increased quantities of protein or amino acids are now given to prevent undue depletion of the body stores of protein. If the patient cannot take even fluid nourishment, intravenous solutions of

[2] Cuthbertson, D. P., Acta, Quart. J. Med., 1, 233, 1932.
[3] Selye, H., "Stress," Montreal, 1950

to which skim milk powder has been added (1 quart milk plus ¼ lb. skim milk powder provides 70 gm of high-quality proteins).

2 Although the adult is called upon to build new tissues only under the exceptional circumstances enumerated above, he nevertheless has a continuous need for protein to provide for *maintenance* of tissues already built This "replacement quota" is not so much necessitated by death of or wear and tear on tissue cells as it is due to their life processes Proteins in the cells are in a state of dynamic equilibrium with the amino acid mixtures (resulting from digestion of protein in foods) brought to them by the blood and extracellular fluids, the cells are continually getting rid of some amino acids to the surrounding fluid and taking up others from it for replacements in the tissues Experiments with amino acids that are "tagged" with N^{15}, an isotope of ordinary nitrogen, have shown that a good deal of this special nitrogen failed to appear in the urine, so that the amino acids containing it must have been rather freely taken up by tissue cells Cellular protein thus seems to be continuously built over by discarding some amino acids and taking on a fresh supply The supply of protein needed for upkeep of the tissues is not inconsiderable and is absolutely indispensable to the well-being of the individual

3 It must not be forgotten that protein can serve as a source of *energy* If protein is eaten over and above the amount needed for tissue building and upkeep, this extra protein will be burned or oxidized. Again, if the diet does not supply carbohydrates and fats in sufficient quantity to meet the energy needs of the body, proteins will be burned as body fuel In this event, some of the protein that would otherwise serve for tissue building or repair will have to be used as fuel and the building or repair processes will suffer The nitrogen, which is an indispensable asset as long as protein is used for tissue building, becomes a liability when it is necessary to burn up protein as fuel It is split off from the constituent amino acids and worked over into simple nitrogen-containing substances (chiefly urea) that are thrown off by the kidneys. The non-nitrogenous fragments of amino acids are then oxidized in much the same way that the digestion products of carbohydrates and fats are subjected to combustion in the body Since body fuel is more economically supplied by carbohydrates and fats, the consumption of protein at such a high level as to be greatly in excess of body need for protein is usually disadvantageous On the other hand, it is certainly unwise to take a low-calorie diet that is likewise low in protein, since the body may then be forced to burn protein as fuel which is needed for tissue building or upkeep

4. Proteins in tissue cells and in body fluids, such as the blood, also serve as *regulatory substances.* Because of their influence on osmotic pressure, proteins exert an important influence on the exchange of water between tissue cells and the surrounding body fluids, and upon the *water balance* of the body as a whole. For instance, after prolonged low level

USES OF PROTEIN IN THE BODY

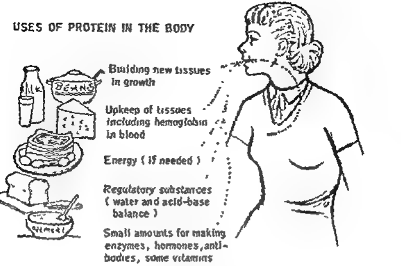


Figure 40

of protein intake the protein content of the blood serum may be less than normal, under such conditions, extra water will be drawn into the tissues and bloating will occur, which is known as starvation, low-protein, or nutritional edema The ingestion of extra protein sufficient to raise the level of serum protein to normal will be followed by excretion of the excess water by the kidneys and disappearance of the edema. Such bloating by retention of extra water in the tissues is often seen in persons who have suffered prolonged undernutrition (as in countries where there is insufficiency of food, especially of protein foods for the poorer people), and in patients who are unable to take much food or who cannot assimilate their food normally

A second regulatory function of proteins is in maintenance of the *acid-base balance* of the blood or of the tissues. The reaction of blood and tissues is normally maintained at about the neutral point, or very slightly alkaline, by balance between several different factors, one of which is their protein content Proteins are able to unite with either acid or alkaline substances, as these may be taken in or arise in the body from metabolic processes When these substances are bound by union with protein, they are without effect on the reaction of the blood or tissues, considerable amounts of acids formed in metabolism may thus be discharged into the blood stream without any "free" acid being present to make reaction of the blood more acid Hemoglobin and oxyhemoglobin in red cells of the blood also help prevent accumulation of carbonic acid (formed by oxidation of foodstuffs) in the tissues by forming loose chemical combination with it and carrying it to the lungs, where carbon dioxide is exercted in expired air

5 Smaller amounts of protein, or of special amino acids furnished

by proteins, are needed for purposes other than actual tissue building—for the making of enzymes[4] that are essential for digestion and oxidative processes in the tissues, for making such potent hormones[5] as those of the thyroid gland (thyroxine), adrenal glands (adrenaline) and pancreas (insulin), for building the antibodies that help ward off infectious diseases, and for building hemoglobin, the oxygen-carrying pigment of the blood. It has also been shown that certain amino acids may give rise to some of the vitamins, e g, an amino acid called tryptophan can act as the precursor of niacin, one of the B-complex vitamins, while another one, methionine, is related to vitamin B_{12} and choline The amino acids supplied by protein are thus essential to the welfare of the body in many ways

Nitrogen Balance and Different Levels of Protein Intake

Nitrogen balance experiments serve to show whether the amount of protein metabolized in the body is equal to, greater than, or less than the amount taken in the food Since nitrogen is supplied only in proteins and makes up (on the average) 16 per cent of the protein, we determine the nitrogen content of the food intake and of the excreta (urine and feces) and multiply these figures by the factor 6 5 (100 — 16) to give the corresponding values as grams of protein The nitrogen of the urine represents a true measure of how much protein has been catabolized or burned in the body during a day, since nitrogen-containing end products of protein metabolism leave the body only in the urine, to get nitrogen intake, we deduct the amount in the feces (unabsorbed protein) from the total in the food When intake and outgo are practically equal, the body is said to be in nitrogen (or protein) equilibrium A positive nitrogen balance, intake greater than output, indicates that new tissue is being built with consequent retention of nitrogen in the body, if output is greater than intake (negative balance), some body protein must have been oxidized in addition to that provided in the food.

The curious thing about nitrogen balance is that it is usually unrelated to the *actual need* for protein for tissue-building and upkeep, since the body can establish nitrogen equilibrium at any level of protein intake that is above the *minimum* requirement Most persons eat more protein than they need and the amount of protein foods consumed varies widely with personal preferences, economic status, and race habits. An American or European man who can afford it prefers to eat about 70–100 grams of protein daily, or even more The Eskimo, who has little except

[4] Enzymes are substances formed in living cells, which speed up or "catalyze" specific chemical reactions without themselves entering into the reaction All of the chemical changes that occur during digestion of food and in body tissues are brought about through the agency of enzymes

[5] Hormones are chemical compounds secreted by the ductless glands into the blood stream and thus distributed throughout the body They act to regulate and coordinate body processes or the activity of certain tissues, e g, thyroxine speeds up oxidative processes by which body fuel is burned and energy set free

fatty meats available for food, may consume in his diet and burn up in his body as much as 300 grams of protein daily without apparent harm. Dwellers in the tropics, where carbohydrate foods (fruits, vegetables, rice, etc.) are so much cheaper and more plentiful than other foods that a low-protein, vegetarian diet is frequently the custom, may be maintained in good health on a protein intake of less than 50 grams per day. The body thus *adjusts the amount of protein it burns to fit the level of its protein intake,* since all protein that is taken over and above the minimum required for maintenance will be burned up.

There is little provision for storing protein in the body. Ordinarily a *positive nitrogen balance,* which indicates protein storage in tissues, is found only in conditions such as growth and pregnancy, when we know new tissues are being formed. Sometimes, after prolonged undernutrition or wasting disease, the protein content of tissues becomes depleted and, on giving plenty of protein, there may be retention of nitrogen while the normal protein content of the tissues is being built up again. Also, on changing from a high level of protein consumption to a diet lower in protein, there is always a few days' lag during which the body adjusts the amount of protein it burns to balance with the lowered level of protein intake. Likewise there is a short delay in adjusting the balance between the amount metabolized and the intake on changing to a higher protein level.

Negative nitrogen balance, of course, inevitably occurs when the protein intake is reduced so low as to be less than the amount required for maintenance of body tissues, the *minimum requirement.* However, it may occur at levels of protein intake that are above the minimum requirement, if the body is forced to burn protein as fuel because the diet furnishes too little of carbohydrates and fats to meet the energy requirement. Carbohydrates and fats are both spoken of as being "*protein sparers,*" since the presence of a liberal quantity of these foodstuffs in the diet does away with the necessity of using protein for fuel. It is es-

[illegible]

ness, otherwise protein will have to be burned as fuel which could be used to better advantage in building or repair of tissues. To put it the other way around, children can make their best growth *only* when their food supplies both a liberal quantity of protein, which furnishes all the amino acids needed for tissue building, and, *in addition,* an amount of fat and carbohydrate entirely adequate to cover their energy needs.

Minimum Protein Requirement for Adults

How can we determine approximately how much protein must be taken daily to provide for maintenance of body tissues in the average man? Dietary studies to find out how much protein is usually eaten will

be of no help, since people consume more protein than their actual need for tissue upkeep, burn up the excess, and adjust to show nitrogen equilibrium at any level of intake above the minimum requirement If we determine the nitrogen excretion when fasting, this figure will also be too high because some of the nitrogen excreted will certainly arise from the necessity of the body to burn protein as fuel to meet the energy requirement The way to get a true measure of the protein actually required for tissue upkeep is to determine nitrogen balance on progressively lower levels of protein intake at the same time that *plenty of carbohydrate and fat are given to meet the energy needs* A figure slightly above the protein level at which negative nitrogen balance appears may be taken as about the intake required for maintenance, or the minimum requirement

Sherman[6] examined data obtained in this way upon 47 different persons and, to make them comparable, calculated each to a common basis of 70 kilograms body weight Although there was quite a range of individual values, the average was about 44 grams of protein per day as maintenance requirement for a man of average weight Sherman has estimated that probably 0 5 gram of protein for each kilogram of body weight would suffice to meet the minimum requirement (35 gm daily for a 70 kg man) A similar level of requirement was given by Hegsted, Stare, and collaborators[7] upon examination of all data available about [illegible] years after Sherman's earlier evaluation, while Bricker[8] found the lower limit for an average man on a diet including both animal and vegetable proteins to be about 30 grams

Few of us would care to live on the minimum level of protein requirement and, in fact, it would be unwise to attempt to limit the protein intake so strictly But the establishment of the minimum actual requirement (at about 0 5 gm protein per kg body weight) is useful in permitting us to gauge the quantity over and above this amount that will provide a suitable margin to cover variations in individual needs, as well as a "factor of safety" to ensure the best nutritional condition

Factors That Influence Protein Requirement

The most important factors influencing protein requirement that need to be considered here are

(1) Size (3) Completeness of digestion and absorption
(2) Age (4) Nature of the proteins eaten

Size of the individual is an important factor in determining the protein requirement The total amount of protein needed for tissue upkeep

[6] Sherman, H C, "Protein Requirement of Maintenance in Man," J Biol Chem, 41, 97, 1920

[7] Hegsted, D M, Tsongas, A G, Abbott, D B, and Stare, F J, "Protein Requirements of Adults," J Lab & Clin Med, 31, 261–284, 1946

[8] Bricker, M, Mitchell, H H, and Kinsman, G M., J Nutr, 30, 269, 1945

is naturally dependent upon the amount of active tissues in the body, for this reason the protein requirement is reckoned as so much *per unit of body weight* If the recommended allowance is placed at 1 gm. per kg (double the minimum requirement to allow a factor of safety), a woman who weighs only 45 kg. (99 lbs.) should have an allowance of 45 grams of protein daily, a tall and muscular man weighing 80 kg (176 lbs.) would rate a daily allowance of 80 grams, which is 10 gm. more than the amount (70 gm.) for a man of "average" weight (70 kg.) shown in the table of "recommended dietary allowances" of the National Research Council Regardless of sex, a person of small body weight will require less, and one of larger than average weight will need more than the "standard" allowance based on "average" body weight. Hence, the daily protein allowance is best calculated *for each individual according to his body weight*

Age is a factor that comes into play chiefly in the younger years when extra protein is needed for building new tissues in growth. Rapidly growing young children may need two to four times as much protein per unit of body weight as adults do, to provide for protein storage in new tissues The high protein requirement of infants and young children is striking when considered per unit of weight, but the total amount needed by their smaller bodies will, of course, be less than the amount needed by an adult Thus the allowance for a two-year-old who weighs 12 kg. (27 lb), even at over 3 gm. per kg., will be only 40 grams protein daily. A slight reduction of protein intake was formerly favored for old people, since it was thought that excess protein might be handled less easily by the body in old age than in the "prime of life" Modern theories give value to liberal (not excessive) protein supplies as one of the factors that favor prolonging vigor into later years Dietary records of older persons sometimes disclose that they are subsisting on considerably less than optimum protein intakes (e g., meats may be mostly eliminated because of low income or difficulty in chewing) *It is now advised that*, although calories should be somewhat reduced, the level of protein intake for old people should be kept about the same as in younger years of adult life.

slightly less efficient for meeting the body's protein needs on this account A protein is of no good to the body until it has been split into its constituent amino acids by digestion, and until these amino acids are absorbed and carried to the tissues However, the loss due to imperfect digestion and absorption normally does not amount to more than 5–10 per cent. Proteins are less completely digested and absorbed when they occur in foods mixed with much indigestible fiber or cellulose, as in a bulky vegetarian diet. This factor may be of considerable importance

when abnormal conditions in the digestive tract greatly limit the digestion and absorption of food. In such cases, it is well to give easily digested protein foods and extra amounts of protein, to allow for the fact that some of it will not be utilized.

The *nature of the proteins* taken in food has such an important influence upon the amount needed for tissue building or maintenance that this factor is taken up separately and in considerable detail in the following pages.

Muscular Work Not a Factor in Protein Requirement

Although muscular work is the largest single factor in determining energy needs, is has no appreciable effect on the protein requirement. The great German chemist Liebig (1803–1873) had the erroneous idea that muscle protein was broken down as the source of energy for work. Soon afterward scientists disproved this theory by climbing mountains, on a diet of carbohydrates and fats, and determining the nitrogen in urine secreted during this time. Since the urinary nitrogen was not appreciably increased, energy for the large amount of physical work must have come from oxidation of the foodstuffs other than protein. Years later, careful experiments by Atwater proved the same fact quantitatively, muscular work sufficient to nearly double the energy metabolism showed very little effect upon the protein metabolized as measured by the nitrogen output.

Although there is no basis for the idea that a man requires extra meat because he is doing muscular work, he does require more fuel foods in order to provide necessary energy. Since protein is an integral part of many foods, such a working man usually increases his protein intake somewhat when he increases his total food consumption. But the energy for muscular work usually comes chiefly from carbohydrates and to prevent exhaustion from severe exercise athletes sometimes take sugar, a quickly absorbed source of body fuel.

BIOLOGICAL VALUES OF PROTEINS AND INFLUENCE ON PROTEIN REQUIREMENT

All molecules of a specific protein are made after a definite amino-acid pattern, but this pattern differs with each individual protein. Nature often varies the number and amounts of the amino acids that make up the protein molecule, sometimes puts in much of one building stone and only a little of another, and leaves out one or more amino acids entirely in making certain proteins. The value of a protein for building tissues depends upon the assortment of amino acids which it provides to the body after digestion and absorption.

Complete and Incomplete Proteins

Some of the first information on how the amino acid make-up of a protein determines its biological value came from the pioneer experi-

A

B

Figure 41 . Stunting of growth due to feeding an incomplete protein as sole source of protein in the diet Contrast between two rats of same age kept on diets alike except for the protein, which was a complete protein (casein from milk) in the case of *A*, and an incomplete protein in the case of *B* (gliadin from wheat) (From experiments by Osborne and Mendel, Connecticut Agricultural Experimental Station, pictures reproduced by courtesy of Yale University Press)

ments of Osborne and Mendel in feeding isolated proteins to rats. Osborne contributed the skill required to obtain proteins in pure form and to analyze them for kinds and amounts of amino acids they contained, Mendel planned and supervised the feeding experiments, so that the rats received a ration adequate in all respects except that only a single protein provided that nutrient In one series of experiments, young rats were fed food mixtures containing 18 per cent of protein in the form of either casein (a milk protein), gliadin (one of the wheat proteins), or zein (a protein from corn) With casein as the sole protein, the rats remained healthy and made excellent growth, those fed gliadin were able to maintain their weight but did not grow much, those whose sole source of protein was zein not only could not grow but lost weight and died eventually if kept on this diet.

Since casein evidently supplied all the amino acids needed for growth, it was said to be a *complete* protein. Gliadin was found to contain too little of an amino acid called lysine to support growth, and when lysine was added to the ration the animals grew normally; since gliadin will provide for maintenance but not growth, it is said to be a *partially incomplete* protein Zein, on the other hand, proved to be an *incomplete* or *inadequate* protein, which supported neither growth nor maintenance because it was lacking on two amino acids, lysine and tryptophan. When the diet was supplemented with suitable amounts of these two amino acids, the animals grew and thrived. These experiments showed conclusively that both lysine and tryptophan must be furnished by the food.

These same investigators also showed that a protein which is adequate when fed at one level may be inadequate at a lower level of intake

Casein at the 18 per cent level provided for normal rate of growth but when it was fed at only 9 per cent of the diet the rats grew only half as rapidly. Casein was found to contain only small amounts of the amino acid cystine, and addition of this substance to the diet led to growth at a normal rate. When a protein is low in some needed amino acid, this is said to be the *"limiting factor,"* for only as much tissue can be built as the smallest amount of necessary tissue ingredient provided. To quote Rose's metaphor,[9] "It would be like taking the word *legume* apart and trying to make the word *muscle*. We should have a superfluous 'g' and 'e', but no 's' nor 'c', and be forced to break up another word, such as *casein*, to get the extra letters."

This illustration also indicates how a protein that may in itself be deficient or low in some amino acid can supplement another protein by furnishing one or more of the amino acids that may be present in insufficient amounts in the other protein. This is shown by the content of casein and zein in six amino acids given below.

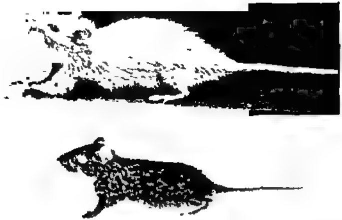
	Casein, per cent	*Zein, per cent*
Lysine	6.3	0.0
Phenylalanine	3.9	7.6
Tryptophan	2.2	0.0
Leucine and isoleucine	9.7	25.[illegible]
Valine	6.7	1.9
Cystine	0.3	1.0

Zein is an incomplete protein because it is entirely lacking in lysine and tryptophan, yet it carries a high quota of leucine and isoleucine and furnishes cystine that will supplement the low content of this amino acid in casein. Both proteins contain other amino acids in addition to the six listed as examples, and may supplement each other in numerous respects as to the amino acids they contribute. Casein has a better balanced amino acid make-up and carries all amino acids needed for tissue building, therefore it is said to be of higher *biological value*. The supplementary value of casein for zein may also be illustrated by an experiment on growing pigs, one lot fed on corn alone and the other on corn plus casein equal to about one-tenth of the corn. In 180 days, the ration of corn alone produced almost no growth, while the comparatively small addition of casein to the corn ration produced growth at about two-thirds normal rate (over 100 pounds, or 9 times the weight gain on corn alone).

Fortunately we have a mixture of protein foods in our diet, and even foods that contain one incomplete protein carry other complete or supplementary proteins. Thus the cereal grains and most legumes each contain one incomplete protein, but they also carry other complete proteins which go far in supplementing and making the amino acid mixture furnished by the food as a whole almost adequate; apparently each of the

[9] Rose, M. S., FEEDING THE FAMILY, p. 16. Macmillan, 4th ed., 1940.

A



B

Figure 41 · Stunting of growth due to feeding an incomplete protein as sole source of protein in the diet Contrast between two rats of same age kept on diets alike except for the protein, which was a complete protein (casein from milk) in the case of A, and an incomplete protein in the case of *B* (gliadin from wheat) (From experiments by Osborne and Mendel, Connecticut Agricultural Experimental Station, pictures reproduced by courtesy of Yale University Press)

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These same investigators also showed that a protein which is adequate when fed at one level may be inadequate at a lower level of intake.

men The 10 essential for rat growth are listed below, along with other amino acids said to be "dispensable," in that they will be made in the body in adequate amounts, chiefly from materials in protein foods

Although the student need not memorize the names of these amino acids, they are currently so much talked about that their chemical names are almost as commonly heard as are those of the vitamins. It is neces-

Names of More Common Amino Acids

Essential		*Non-essential*	
Arginine	Methionine	Alanine	Glycine
Histidine	Phenylalanine	Aspartic acid	Hydroxyproline
Isoleucine	Threonine	Citrulline	Proline
Leucine	Tryptophan	Cystine	Serine
Lysine	Valine	Glutamic acid	Tyrosine

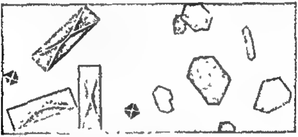

Figure 43 Crystals of two pure amino acids (left) alanine and (right) valine Alanine is not an essential amino acid but valine is (Sahyun, OUTLINE OF THE AMINO ACIDS AND PROTEINS, Reinhold Publishing Corp)

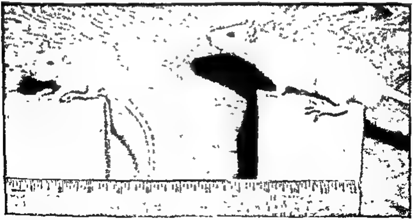

Figure 44 Effect of Lysine Deficiency on the Growth of the Rat. The animals

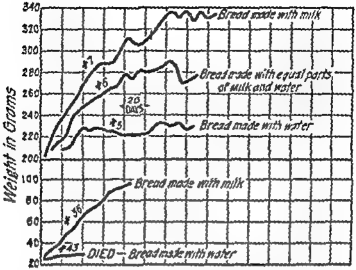

Figure 42 Contrasting effects of bread made with water and with milk. Milk proteins supplement those of grains in promoting growth (Courtesy of Dr H C. Sherman and the Journal of Biological Chemistry)

seeds furnishes all necessary amino acids but some of them are in inadequate quantity for best growth, so that they still need be supplemented by some animal protein in the diet In general, the proteins of milk, meats, and eggs are especially valuable for supplementing those of the grains and legumes Soybean flour (at levels of 10 to 15 per cent) supplements the proteins of white wheat flour with effectiveness practically equal to the protein of meat, eggs, and milk The addition of milk solids, soybean or peanut flour, or wheat germ to white flour is highly recommended to improve the nutritive efficiency of the protein content of bread Even gelatin (an incomplete protein lacking in tryptophan and tyrosine, but high in lysine) and the incomplete proteins of beans have an amino-acid contribution to make in a mixed diet

Essential Amino Acids

Of course all of the 20 or more amino acids that are constituents of body tissues are essential to provide for growth and maintenance of tissue protein But recent studies have shown that about half of them can be formed in the body, while the others must be furnished pre-

for normal growth ' Rose and co-workers at the University of Illinois found that for the growth of young rats 10 different amino acids must be supplied in adequate amounts in the food, whereas only 8 of these were essential for maintenance of nitrogen equilibrium in fully grown young

amino acids required to just maintain nitrogen equilibrium in man,[11] and set double these amounts as desirable allowances in the diet.

From calculations of the amino acids provided in numerous diets, it would seem that there is little danger of shortage of essential amino acids in an ordinary American diet. In such dietaries, Block and Bolling[12] found that 20–30 per cent of the essential amino acids were contributed by milk, cheese, and ice cream, 15–35 per cent from meat, poultry, and fish, 15–30 per cent from grain products, 6–10 per cent from eggs, and the balance (usually 10–18 per cent) from legumes, potatoes, and other vegetables and fruits. Thus, probably over 50 per cent of the essential amino acids in the average American diet are in the form of high quality animal proteins. The people of many other countries are not so fortunate and must rely more largely upon vegetable proteins; when this is the case, the vegetable sources should be varied[13] and supplemented, if possible, by some available animal protein, while a larger total amount of protein may be needed.

Influence of Quality of Protein on Protein Requirement

It should be evident that, if a protein has a low content of one or more essential amino acids, it will take more of it to satisfy the protein requirement. Enough of it must be taken to provide the minimum requirement for the essential amino acid that is in poorest supply or is the "limiting factor." Proteins that have a well balanced quota of essential amino acids are most efficient in promoting growth or maintaining the body in nitrogen balance. Casein, lactalbumin (a second protein in milk), and edestin (found in nuts) are all complete proteins, yet Osborne and Mendel found that only 8 per cent of lactalbumin in the diet produced the same weight gain as 12 per cent of casein and 15 per cent of edestin. As they state the results, "to produce the same gain in body weight, 50 per cent more casein than lactalbumin was required, and of edestin nearly 90 per cent more."

The above experiments were made with a single pure protein as sole source of protein in the diet; we take a mixture of protein foods and even one food usually contains several proteins that supplement each other as to amino acid make-up. Nevertheless, it is possible to demonstrate that, even for maintenance of the tissues in fully grown human beings, some types of natural foods provide protein mixtures that are more efficient than others. In general, proteins of animal origin (as in

[11] Rose, W. C., "Amino Acid Requirements of Man," Fed. Proc., 8, 546–552, 1949.

[12] Block, R. J., and Bolling, D., THE AMINO ACID COMPOSITION OF PROTEINS AND FOODS, Charles C Thomas, 2nd ed., 1951.

Figure 45. Students, volunteers on Dr Rose's diet squad for determining the

University of Illinois)

sary to refer to them by name in discussing the amino acid make-up of different proteins, and the essential amino acids are just as necessary in the food supply as are the individual vitamins

Rose and associates found out which amino acids could be formed in the body and which could not by a new procedure that took chemical skill and years of painstaking work [10] They hydrolyzed protein, prepared pure amino acids, and fed a well balanced mixture of these substances as the sole source of nitrogen in an otherwise adequate diet Then, one by one, they withdrew certain amino acids and observed the results If the amino acid could be made in the body, no untoward results followed; but when the amino acid was essential in the food, growth ceased in the young rats or negative nitrogen balance developed in the young men.

essential for growth in humans or to protect the body in time of stress and strain. Rose also determined the *quantity* of the different essential

[10] Rose, W C, "The Nutritive Significance of the Amino Acids," Physiol. Rev, 18, 109–136, 1938.

of the United Nations have brought to attention the prevalence of "protein malnutrition" in underdeveloped countries, and these agencies have defined the condition as "A state of ill health occurring where diets *are habitually poor in protein while they are more nearly adequate in* calories" Those most apt to show marked symptoms as a result of too little protein, or an imbalance of amino acids supplied by the food, are young children in the years immediately after weaning, usually under five years of age Naturally, with too low supply of amino acids for building tissue protein or with some of the essential ones present in too small quantities, there is failure to grow properly, wasting of tissues, and edema, shown by swollen abdomen, these symptoms are common to protein deficiency, and even to semi-starvation, the world over

However, a new and peculiar type of symptom-complex due to protein malnutrition has received much attention in recent years, with study of its cure and prevention In Central Africa, where it was first recognized and mortality from it is very high, it is known as "*kwashiorkor*," a word which means "red boy"[14] The name comes from the odd reddish-orange color of the hair, as well as from a skin rash, characteristic *of the disease Other symptoms are weakness and nervous irritability*, inability to digest and absorb food normally, anemia, and fatty infiltration of the liver Since the foods that provide animal protein also carry various B-vitamins and minerals (such as iron), kwashiorkor is probably a protein deficiency complicated with deficiency of certain minerals and vitamins The FAO has reported that the same condition of disturbed nutrition occurs in many other sections where the diet is similar, and is known by many names such as "sugar baby," infantile pellagra, fatty liver disease, or nutritional edema syndrome Dried skim milk is one of the most effective foods for use in treatment (or prevention) of such protein malnutrition in children Even those in critical condition usually respond dramatically to such treatment and can be restored to health (with return of normal hair color) in a few weeks (see Fig 46, p 110) Where milk is not available or is costly to import, other animal protein foods may be used or an assortment of vegetable foods may be found which supplement each other as to amino acid content of proteins These provide the well balanced mixture of amino acids that is needed A variety of cereals or root vegetables, addition to the diet of peanut or soybean flour, other legumes, or dried yeast may serve to provide such an adequate mixture of proteins, an increase in the total amount of protein intake is also usually required

Although kwashiorkor and similar conditions occur only in young children in the period after they are deprived of their mothers' milk and are not yet able to properly assimilate the bulky, fibrous adult diet, there

[14] "Kwashiorkor in Africa," World Health Organization, Geneva, 1952, Brock, J F, "Survey of the World Situation on Kwashiorkor," Ann N Y. Acad Sciences, 57, 696, 1954.

eggs, milk, cheese, and meats) are usually classed as having higher *biological value* than most vegetable proteins, although those found in soybeans, peanuts, peas, and most nuts rate highly. Vegetable proteins, such as those in cereal products, potatoes, and leafy vegetables, have an important value in the diet (especially when eaten in considerable quantities), since the amino acid mixtures they provide supplement those in animal foods. Conversely, a vegetarian diet can be made entirely adequate in quality of proteins by supplementing vegetable proteins with some milk, cheese, or eggs, protein foods which most vegetarians use. In the parts of the world where these and other foods of animal origin are scarce or not available, it is difficult to obtain a diet that provides all essential amino acids in proper amounts and the balanced mixture required for health People may cram their stomachs with bulky vegetable foods and still suffer from protein deficiency.

In order to be of high biological value, a protein (or protein mixture) must be well *digested* and absorbed, as well as possess suitable amino acid content Other factors that influence the percentage of nitrogen from the food that is absorbed and retained by the tissues (the biological value) are the *heat treatment* to which a food may have been subjected in cooking or processing, the other foods with which it is eaten, and the distribution of protein foods in the meals throughout the day. The protein in legumes is rendered more digestible by cooking, but high heating of cereals (as in toasted or puffed breakfast cereals) and milk (as in processing of some canned milks) seems to cause structural changes in the protein molecule that make the nitrogen less available. Since all of the essential amino acids must be present in the blood stream at the same time in order to promote building of tissue proteins, nitrogen retention will be best when some complete proteins (usually animal proteins) are taken in each meal.

PROTEIN DEFICIENCY AND AMINO ACID IMBALANCE

Protein Malnutrition: A World Problem

As stated above, there are many areas of the world, in underdeveloped and overpopulated countries, where protein-rich foods, especially those of animal origin, are either scarce or practically unavailable. In many parts of Asia, Africa, the West Indies, Central and South America, milk is not available at all, eggs and meats are so rare and costly as to be out of reach of the common people, while fish are available only in coastal regions to supplement the diet with animal protein. The diet is primarily from vegetable sources and rich in starchy foods, such as rice, corn, cassava or taro roots, peas and beans The poorer people can hardly get enough calories, certainly not an adequate supply of protein or a well balanced mixture of amino acids, on the foods they can raise or buy. Recent surveys and studies made by the health agencies

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are evidences that older children and adults in these same areas suffer, even if less markedly, from prolonged inadequacy of protein in the diet. In Central Africa, where almost every young child shows some symptoms of kwashiorkor, it has been found that many adults have fatty livers. In Mexico and Central America, where corn and beans are the chief sources of protein, children who survive the post-weaning period often make less than normal growth (Fig 3, p 6). And in Ceylon, Nicholls[15] found that boys from poor families make slower growth than those from well-to-do families, whose diets contain more of the high-quality proteins. The work of the United Nations health agencies has been directed toward securing more adequate diets for peoples in underdeveloped countries. This can be done by encouraging them to raise more of crops that provide good quality proteins, educating them to use a wider variety of foods and, by raising the economic level, enabling them to import some high-quality protein foods such as dried milk.

In the United States, Canada, and most European countries, protein malnutrition is not a real public health problem, since animal foods are sufficiently abundant and usually ½ to ⅔ of the protein intake comes from these sources. In addition, the average caloric intake is so high that protein does not need to be burned in the body to supply energy. The table given below, compiled and simplified from figures reported in 1952 by two separate United Nations agencies,[16] lists average levels of caloric intake, total protein intake, relative amounts of animal protein, and average life expectancy in four countries where the diet is below that desirable and four in which it is unquestionably adequate in both calories and protein.

Although life expectancy is, of course, influenced by many other factors (sanitation and medical care, adequacy of minerals, vitamins, etc.), it is interesting to note that increase of life expectancy closely

Table 7. Correlation of Diet with Life Expectancy

	Calories per person per day	*Protein per person per day, grams*	*Percentage of Protein from Animal Sources*	*Life Expectancy, years*
India	1,700	44	13	27
Japan	2,100	53	15	58
Mexico	2,050	55	29	39
Venezuela	2,160	60	38	47
France	2,770	99	40	65
United Kingdom	3,100	92	53	69
United States	3,130	90	66	69
Australia	3,160	95	68	[illegible]

[15] Nicholls, L., Tropical Nutrition and Dietetics, Baillière, Tindall, and Cox, 1951.

[16] FAO, U. N., Second World Food Survey, 1952, U. N., Dept. of Social Affairs, Preliminary Report of the World Social Situation, 1952.

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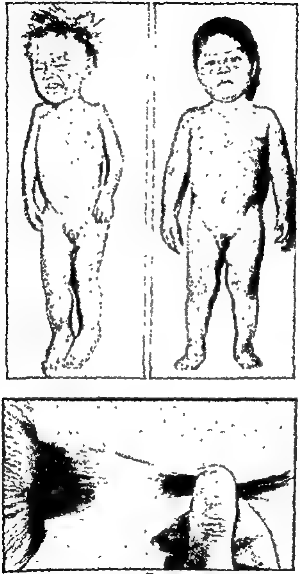

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countries where animal foods are unavailable, they represent an unneeded fad in the United States (or an attempt to promote the sale of cereal foods) where milk or meats are freely used and effectively supplement the amino acid shortages of cereal foods

STANDARD PROTEIN ALLOWANCES FOR ADULTS AND HOW TO SECURE THEM IN THE DIET

We have seen in the preceding pages how many influences come into play to affect the quantity of amino-acid intake that will be retained in the body for tissue building or upkeep—such as the quantity of carbohydrate and fat in the diet, the quantity, quality, and digestibility of the various proteins ingested, the state of the body, and the distribution of the protein over the day's meals—to mention only a few Since conditions may be more favorable for nitrogen assimilation at one time and much less favorable at another, it is reasonable that the diet should supply some extra protein over the minimum requirement, as a "factor of safety" to ensure plenty under any condition How liberal should this extra amount be?

Different Levels of Protein Intake

The consumption of protein varies with different peoples from about [illegible] to 200 or more grams of protein daily Arguments vary as to whether a low- or high-protein diet is more conducive to health Chittenden, who was the original proponent of a low protein intake, maintained that he was freer from minor ailments and more vigorous on such a diet and, as he lived to be over 80 years old, he apparently suffered no harm Other cases are on record of persons who pursued vigorous lives on intakes of less than 50 grams of protein daily On the other hand, most of the "bogeys" supposed to attend the taking of too much protein have been disproved Stefansson maintained a high degree of physical and mental well-being on an all-meat diet in the Arctic for long periods, totaling in all nine years, two men, who lived for a year under observation by DuBois while subsisting on an exclusive diet of meat (daily intake 100–140 gm protein, 200–300 gm fat, only 7–12 gm carbohydrate), showed no ill effects (such as elevation of blood pressure or kidney damage supposed to be associated with overeating of protein) when examined at the end of the test If the liver (an organ essential in protein metabolism) is damaged, high protein diets may prove dangerous The consensus of opinion now is that a *liberal* margin over the minimum requirement is good insurance against times of stress, but that *superabundant supplies* provide no added advantage

The protein allowance and factor of safety should be especially liberal in conditions of growth or repair of body tissues, such as childhood, pregnancy and lactation, recovery from malnutrition, or conditions where assimilation of food is poor A generous factor of safety may also be valuable when proteins of lower biological value make up a large

parallels increase in the quantity and quality of protein in the diet. In general, countries where both the caloric and protein intakes are fairly low and considerably less than ⅙ of the protein is of animal origin, life expectancy is relatively lower; when both calories and protein are provided liberally and ½ to ⅔ of the protein is from animal foods, one can expect more years of life. There is little doubt that adequate quantity and quality of protein supplied in the diet is one factor essential for health

Amino Acid Imbalance and Supplementation of Foods

We have seen (p 102) that individual proteins may be high in content of certain amino acids and low in others (partially incomplete), or they may even be entirely lacking in one or more essential amino acids (incomplete or inadequate proteins). Such proteins provide an unbalanced assortment of amino acids, but in the ordinary mixed diet the proteins of some foods supplement those of others in amino acid content, so that a well *balanced* mixture of amino acids is provided for use in the tissues This is practically sure to be true if the protein intake is fairly liberal and at least half of it is furnished by foods of animal origin (dairy products, eggs, meat, fish, or poultry), for growing children, it is suggested that two-thirds of the protein should be from animal foods. The average diet of adults in the United States would not only supply plenty of protein but all of the essential amino acids in amounts far above the level decided upon as "safe" for maintenance

However, in countries such as those noted above, where protein intake is low and most of it is furnished by vegetable foods, some of the essential amino acids may well be provided in too small amounts (amino acid imbalance) The proteins of cereal grains are known to be low in lysine (an amino acid especially needed for growth), corn is deficient in tryptophan and lysine, and legume proteins are deficient in tryptophan and methionine White potatoes have a good balance of amino acids except for a shortage of methionine. Since these foods furnish a large proportion of the calories in many parts of the world, lysine, tryptophan, and methionine are the amino acids most likely to be furnished in less than adequate amounts in human diets. Flodin[17] has suggested the possibility of preventing protein malnutrition (as seen in kwashiorkor) by supplementing the diets in those parts of the world where it is prevalent with these three amino acids (and probably also threonine) Experiments have also been made in impregnating cereal foods (wheat flour, rice, corn grits, etc.) with lysine and methionine (corn also with tryptophan), wheat that had its lysine content doubled proved twice as effective for tissue building in growth as ordinary wheat. Although some such processes may later prove a boon in underdeveloped

[17] Flodin, N. W., "Amino Acids--Their Place in Human Nutrition Problems," J. Agr. & Food Chem., 1, 222, 1953.

remains constant Calculation on the basis of a percentage of caloric intake is also more

the calculation on percentage of calories works approximately only because their high protein needs are accompanied by an increased caloric allowance per unit of body weight Small or very sedentary women and old people may well be allotted too little protein on this basis, since their appetite and energy needs are low but their protein needs may not have decreased correspondingly

How To Secure Protein Allowance in the Diet

For the average *adult* sufficient protein of excellent quality will be ensured if the following foods are included in the dietary every day—

Milk, 1 pint (2 glasses) 1 average serving meat 1 or 2 servings of other protein-rich food	furnishing 40–50 gm protein

The "other protein-rich food" mentioned above may be

1 egg,
½–¾ c legume,
2 tbsp peanut butter,
1 rounded tbsp cottage cheese,
1 oz American cheese,
1 serving leftover meat dish

Grain products and the vegetables and fruits needed to make an adequate diet may be relied upon to provide about 20 grams of protein, which will make up the protein ration to 60–70 grams, which is about the amount usually recommended for the average adult

To show how this rule might be worked out at three different cost levels and for persons who are either heavy or light meat eaters, the following foods are listed with the number of grams protein they furnish

High cost	*Protein, gm*	*Moderate cost*	*Protein, gm*	*Low cost*	*Protein, gm*
Milk, ½ pint	8 5	Milk, 1 pint	17 0	Milk, 1 pint	17 0
Ice cream, ⅙ quart	4 4	Hamburger patty, 3 oz	19 8	Beef chuck, potroasted, 2 oz	15 6
Roast beef, 4 oz	28 8	1 egg	6 1	Pork and beans, canned, ⅔ cup	10 0
Creamed chicken, ½ cup	17 [illegible]	Cheese, Am cheddar, 1 oz	7 1	Cottage cheese, rounded tbsp	5 5
	59 3		50 0		48 1
White bread, 2 [illegible]	4 0	Whole wheat bread, 3 sl.	6 3	Whole wheat bread, 4 sl	8 4
Rice krispies, 1 cup	1 9	2 med potatoes	4 [illegible]	Oatmeal, 1 cup	5 4
2 med. cup cakes	5 [illegible]	Apple pie, ⅙ pie	3 8	1 lg potato	3 6
1 med potato	2 4			Bread pudding w. raisins, ¼ cup ..	8 9
	72 6		64 9		74 4

Two servings each of fruits and vegetables will add 4–7 gm. protein

portion of the intake, for instance on vegetarian diets or when economy limits the amounts of animal protein.

Standard Allowances of Protein

The daily allowances of protein recommended (1958) by the Food and Nutrition Board of the National Research Council for adults and "teen-agers" are as follows:

Man (70 kg., 154 lbs.)	70 gm. protein	Lactating woman	+40 gm. protein
Woman (58 kg., 128 lbs.)	58 " "	Girls, 13–20 yrs.	75–85 " "
Pregnancy (2nd half)	+20 " "	Boys, 13–20 yrs.	85–100 " "

The allowances for normal adults are based on 1 *gram of protein per kilogram of body weight* (or about 0.45 gm. per pound); if the minimum requirement of about 0.5 gram per kilogram weight is accepted as correct, a 100 per cent factor of safety is provided. Authorities agree that such an allowance gives a safety margin of 50 to 100 per cent above the normal requirement for maintenance.

The protein allowances given above are for adults of "average" weight. For a man or woman whose body weight is less than average, for example 55 kg. (121 lbs.), the standard allowance would be 55 gm. protein. A large and muscular man who weighs 80 kg. (176 lbs.) should have at least 80 gm. protein per day and may eat considerably more, perhaps 120 gm. Many persons are better satisfied on a somewhat more liberal protein intake and a moderate excess does no harm.

The allowances for pregnant and lactating women, and for young people (13–20 years) who are growing and maturing (also for young children), provide more than 1 gm. protein per kg. body weight. A woman who weighs 60 kg. (132 lbs.) in the second half of pregnancy should have 80 gm. (60 + 20) protein daily, the same weight woman if lactating has a daily allowance of 100 gm. (60 + 40) protein. A growing boy (63 kg. or 139 lbs., 16–19 years old) has a protein allowance of 100 gm. per day. Allowances for younger children (which are as high as 3–4 gm. protein in rapidly growing infants) will be found in the chapter on diet for children.

In calculating the standard protein allowance on the basis of body weight, some consideration should be given to body composition. The protein allowance of 1 gm. per kg. body weight is based on the amount of *active tissues* in an individual with *average* body composition. The protein requirement may be slightly higher in an unduly lean or muscular person and will be somewhat lower in persons in whom fat makes up an undue proportion of body weight.

need for calories, ... habit *may* cause people to overeat or undereat as to calories, but their protein need

= 1 kg.) Allowing 1 gram of protein for each kilogram of body weight, what should be your daily protein allowance? Why is the protein allowance based on body weight? If the actual requirement for protein is only about 0.5 gm. protein per kg. weight, why is the protein allowance twice that amount.

5. Record your food intake for 1 day. What protein-rich foods and how much of each did you take? Using the table of nutritive values of foods in the Appendix (pp. 563 to 581), compute how many grams of protein your day's diet provided. Compare this with your standard allowance for protein and, if your protein intake was as much as 20 per cent lower than that recommended, make suggestions as to how to bring the level up to the desirable one. Does it matter if you are eating more protein than the standard allowance? If so, why, if not, why not?

6. Which of the foods in your day's diet record furnished complete or high quality proteins? Which foods contained some incomplete proteins? What percentage of your day's protein was in the form of high quality proteins? How were the incomplete proteins useful? Why can they not be depended on as the sole sources of protein in the diet?

*7. Arrange a list of the chief protein-bearing foods in order of their relative costliness. Plan a low-cost diet for one day that will furnish 60–70 grams protein using the following as a nucleus.

1 pint of milk
2 oz. serving of lower cost meat
2 servings of other protein-rich foods of lower cost

Fill out the menus with enough bread, cereals, potatoes, and other low-cost vegetables to make up the protein allowance. Use tables given below and in Appendix.

*8. Plan a day's diet for a vegetarian, which excludes meat and eggs but includes milk and/or cheese, and which furnishes 60–70 grams protein. Use tables below for protein substitutes for 1 serving meat and 1 egg.

Foods Which Furnish Same Amount of Protein (approx.) as

1 serving meat (3 oz.)	1 egg
1½ cups cooked dried beans or peas	¾ cup fresh lima beans or green peas
1 cup cooked soybeans	1½ tbsp. peanut butter or 2½ tbsp. chopped peanuts
3 oz. American cheese	⅓ cup (1½ oz.) chopped nuts
½ cup cottage cheese	1 oz. American cheese or 1 rounded tbsp. cottage cheese
2½ full glasses milk	¾ glass (6 oz.) milk

* It is suggested that half the class work out question 7 and the other half question 8.

It will be seen that the above lists of foods will provide at least 65 to 75 grams of protein (with about 60 per cent of it of animal origin), or about the *amount needed by a man of average weight.* Of course a vegetarian diet can be made entirely adequate in quality of proteins by supplementing vegetable proteins with milk and milk products and/or with eggs, but most Americans prefer to eat meat at least once a day. Meats are one of the most expensive ways in which to purchase protein, but they furnish it in concentrated form, a 3 oz. serving of meat may be depended on to give 15–25 grams of protein (depending on its fat content and how much moisture has been lost in cooking), or about ⅕ to ⅓ of the adult's daily ration Fish, shellfish, and poultry are in the same class with red meats as protein carriers Among the least expensive foods for protein are dried legumes, cereal products, potatoes, and milk, especially dried skim milk

Does it make any difference how we distribute the day's protein *ration between the three meals? Normally we are apt to include one* protein-rich food in each meal, partly for its satiety value. Breakfast may be an exception for those who eat a hurried or light meal in the morning In order to promote maximum retention of nitrogen in the tissues, all of the essential amino acids should be in the blood stream during the absorptive period following a meal, hence it is advised now that each meal should include some food that carries protein of high biological value, such as proteins of animal origin For breakfast, this may be met by milk to drink or on cereal, or by including an egg, a light lunch may include a meat, peanut butter, or cheese sandwich, egg or meat in a salad, or a glass of milk Inclusion of some high quality protein in each meal is especially important in periods or conditions when storage of protein in tissues is most desirable, such as growth, pregnancy, or recovery from wasting illnesses

QUESTIONS AND PROBLEMS

1 What factors determine the need of the body for protein? Explain the difference between these terms and the meaning of each—minimum protein requirement, standard allowance of protein, actual protein intake, protein storage, metabolized protein

2 How and why do the protein needs of children differ from those of the adult? Under what special circumstances does an adult require extra protein *for tissue building or repair? Why does the quality of the* protein taken influence the quantity that is needed?

3. Discuss what is meant by the biological value of a protein. What factors determine its biological value? How many amino acids must be furnished preformed in the food of man? What will happen if these amino acids, or any one of them, are provided in less than adequate amounts?

4. Weigh yourself and calculate your weight in kilograms (2 2 lb.

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tions) are the chief constituents of practically all the organic compounds found in the body, especially fats, carbohydrates, and proteins *Nitrogen* is an essential constituent of proteins (most of which also contain sulfur, and some of which also contain phosphorus and iron) These four elements make up 96 per cent of body weight and are supplied by carbohydrates, fats, and proteins in the food

MINERAL ELEMENTS

The other elements listed (Fig 47) in the tabulation of the chemical elements of the body are commonly referred to as the *mineral elements* or the inorganic foodstuffs, or sometimes as "ash constituents," since they make up the ash left after burning up the organic or combustible portion of foods or body tissues It should be clearly understood, however, that some of them exist in foods or tissues as inorganic salts, but a considerable amount of them are held in combination in organic compounds. Thus phosphorus may be a constituent part of various organic compounds in the tissues and of certain fatlike substances, proteins, and carbohydrates in the food In most cases, the mineral elements are sup-

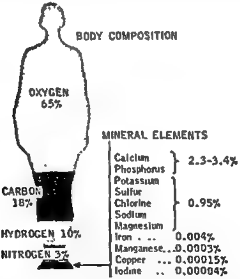

Figure 47 The non-metallic elements oxygen, carbon, hydrogen, and nitrogen together make up 96 per cent of the body weight, leaving only 4 per cent for all the various mineral elements Calcium and phosphorus are the mineral elements present in largest amounts, but these amounts vary considerably according to the reserves of these [illegible]

to be essential

Why the Body Needs Mineral Elements, Water, and Fiber

BODY COMPOSITION

The body is made up structurally of *cells, tissues*, and *organs*, but these in turn are all composed of different *chemical elements*, held together in many and varying forms of chemical combination The chemical elements are thus the ultimate building stones of the human body, the composition of which is shown graphically in Figure 47 on page 121

It will be seen that the element oxygen constitutes over half of the body by weight, while oxygen and hydrogen together make up three-fourths of the body weight The prominence of these two elements is largely accounted for by the fact that two-thirds of the body weight consists of water, which is a compound of oxygen and hydrogen (weight ratio of 16 to 2). *Carbon, oxygen*, and *hydrogen* (in varying propor-

tions) are the chief constituents of practically all the organic compounds found in the body, especially fats, carbohydrates, and proteins *Nitrogen* is an essential constituent of proteins (most of which also contain sulfur, and some of which also contain phosphorus and iron) These four elements make up 96 per cent of body weight and are supplied by carbohydrates, fats, and proteins in the food.

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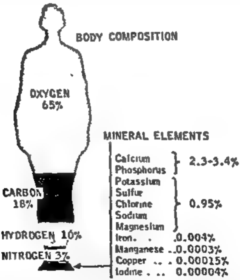

Figure 47 The non-metallic elements oxygen, carbon, hydrogen, and nitrogen together make up 96 per cent of the body weight, leaving only 4 per cent for all the various mineral elements Calcium and phosphorus are the mineral elements present in largest amounts, but these amounts vary considerably according to the reserves of these two elements stored in the bones Iron, manganese, copper, and iodine are present in minute quantities, though vitally important. Cobalt, fluorine, molybdenum, silicon, and zinc have been shown to be present in the body in trace amounts and doubtless have some function other trace elements have been found in the body but not yet shown to be essential.

plied to the body chiefly in the form of mineral salts, found mixed with or combined with the organic foodstuffs in foods as they occur in nature (especially in plant foods). Highly purified or refined food substances such as pure fats, cane sugar, corn starch and highly milled grains are practically free from mineral elements

It should be noted that the mineral elements or ash constituents together make up only 4 per cent of the total body weight; if the body of a 154 pound (70 kg.) man were burned up as completely as possible, there would remain behind only about [illegible] pounds of ashes, a very large proportion of which would consist of salts of calcium and phosphorus (calcium phosphate) *from* the bones. Sodium, potassium, magnesium, sulfur, and chlorine *together* make up less than 1 per cent of body weight Many mineral elements exist in the intact body in traces only. In fact, a "trace element" has been defined as one that is present in "not more than one part in twenty thousand of the organism, approximately the proportion in which zinc and iron are present in the tissues of man"[1]

Even though needed only in small, or minute, amounts from day to day, each and every one of the essential mineral elements is as necessary for building tissues and maintaining the life processes of body cells as is a suitable supply of energy and of all the essential amino acids furnished by proteins. It is impossible to say that certain ones are more important than others, despite the fact that some (such as calcium and phosphorus) are required in much larger amounts than others For instance, iron is one of the elements most vital for the well-being of the body, although only a few thousandths of a gram of it is needed daily This element is required for making hemoglobin, the pigment in red blood corpuscles that enables them to carry oxygen to and carbon dioxide away from the tissues, both of which functions are essential to the life of tissue cells In turn, copper is indispensable in the process of forming hemoglobin, although not present in it. copper probably functions in some enzyme that plays a part in hemoglobin formation, which explains why such small amounts of it are needed. Thus animals that get too little copper in their food will develop anemia, even though plenty of iron is supplied

Most of the metallic elements needed in "trace" amounts appear to *function* as a part of enzymes, hormones, or vitamins required to bring about some essential chemical reaction in the tissues Cobalt is known to be an essential component in vitamin B_{12}, a vitamin that assists in formation of new red blood corpuscles, iodine is an essential component of the hormone thyroxine, made by the thyroid gland, zinc functions as part of the pancreatic hormone, insulin, while magnesium has also been shown to be linked to some enzymes that are essential to body oxidations

[1] Barcroft, Sir Joseph, "Trace Elements in Relation to Health," Proc Nutr Soc, 1, 192, 1944.

Table 8. Need for Mineral Elements

	Elements especially needed	*Results of lack of these elements*
As building materials		
Bones and teeth	Calcium and phosphorus	Stunted growth; Weakened or soft bones; Malformed or decaying teeth; Rickets
Hair, nails, and skin	Sulfur	
Soft tissues—chiefly muscles	All salts, esp potassium, phosphorus, sulfur, chlorine	
Nervous tissue	All salts, esp phosphorus	
Blood	All salts, esp iron, calcium, sodium, phosphorus, chlorine	Lack of iron or copper (or both) results in less than normal amounts of hemoglobin in blood, a condition called nutritional anemia
Glandular secretions	Stomach secretions—chlorine; Intestinal secretions—sodium; Thyroid secretion—iodine	Lack of iodine results in enlargement of thyroid gland, simple goiter

	Elements especially needed
As body regulators	
To maintain *normal*	
(1) Exchange of body fluids	All salts
(2) Contractility of muscles	All salts, especially balance of calcium *vs* sodium and potassium
(3) Irritability of nerves	All salts, especially balance of calcium *vs* sodium and potassium
(4) Clotting of blood	Calcium
(5) Oxidation processes	Iron and iodine
(6) Neutrality of body	Balance between Basic elements—sodium, potassium, calcium, magnesium, and iron; Acidic elements—phosphorus, sulfur, and chlorine

Fortunately almost all of the "trace" elements are found in minute amounts in so many foods that they are not apt to be lacking in the normal human dietary Some of them, known to be needed by lower animals, have not yet been proved essential for man The occurrence of deficiencies of trace elements in animals grazing on plants grown on soil that is deficient in the given elements has suggested the possibility of similar deficiencies in man, but it has been stated that "With the exception of iodine, no acceptable evidence has appeared for the occurrence of a deficiency of trace elements in man attributable to a lack of them in the soil"[2]

Although there is no reason to regard *fluorine* as an essential nutrient, this element is mentioned briefly here because of the widespread

[2] McLester and Darby, NUTRITION AND DIET IN HEALTH AND DISEASE, p 108 Saunders, 6th ed, 1952.

attention given recently to its relation to dental health. Like most of the trace elements, excessive amounts have toxic effects (the most marked being stiffening of the backbone which prevents bending over). Dental interest was first concerned because a "mottling" of the teeth (chalky white spots that later stain yellow or brown) was found to occur in certain areas where the drinking water was unusually high in fluorine. Concentrations of 2 parts of fluorine per million parts of water caused mottled teeth, but at levels of 1 part per million, fluorine in drinking water not only caused no harm but had the beneficial effect of reducing the incidence of dental caries Hence, addition of fluorine compounds to city water supplies (up to 1 p p m) has been advocated to improve dental health and tried out successfully in several cities The best prevention of caries is obtained among young children, when fluorine to harden tooth enamel is available during the period of tooth formation Present evidence indicates that consumption of water containing 1 part per million fluorine is safe

Iron, iodine, calcium, and phosphorus may be either distributed so unevenly in foods or found in them in such small amounts that a freely chosen dietary may provide less than the required quantity for man. Because of this fact, and also because of the importance of their functions in the human body, special chapters will be devoted to consideration of these elements (Chapters 8 and 9). A general discussion of how mineral elements function in the body appears on the following pages.

MINERAL ELEMENTS AS BUILDING MATERIALS

Distribution in Tissues

The upper part of Table 8 (p 123) shows a résumé of certain elements especially needed for building certain tissues. Sherman[3] groups the mineral elements in tissues into three classes, as follows:

(1) As constituents of hard tissues—bones and teeth,
(2) As essential elements of soft tissues, chiefly in organic compounds,
(3) As constituents of body fluids—chiefly as soluble inorganic salts

1. The bulk of the mineral substances in the body is concentrated in the skeleton or bony framework. It is because the chief mineral constituents of *bones*, on which their rigidity and relative permanence depend, are insoluble compounds of calcium and phosphorus that these two elements occupy such a prominent place quantitatively in the mineral composition of the body About 99 per cent of the calcium and 90 per cent of the phosphorus in the body are found in the bones and

[3] Sherman, H. C., Chemistry of Food and Nutrition, p. 229 Macmillan, 8th ed., 1952.

teeth Insoluble calcium phosphate is deposited in the matrix of bones and teeth in crystalline structure resembling that of phosphate rocks, some calcium carbonate is also present, with small and variable amounts of silicon and fluorine In the earliest years of life (and even before birth), a plentiful supply of calcium and phosphorus is necessary (along with vitamin D which helps put them in place in bone) to build strong bones and teeth. After these structures are built, they are relatively permanent, although daily supplies of these mineral elements are needed for their upkeep The bones and teeth constitute a reservoir of calcium and phosphorus for the body, the supply of these elements found in the "trabeculae" or meshwork at the ends of bones is more "labile" and can be drawn on more readily than that in the long bones Silicon and fluorine occur in the enamel of teeth, the former having no special significance

2. The *soft tissues* are chiefly the muscles, glands, and nervous tissues The primary units of each of these tissues are cells, each of which consists of a nucleus and protoplasm Phosphorus is a constituent of the organic compound, nucleoprotein, found in every cell nucleus, and of fatlike compounds, phospholipids, which are especially abundant in nervous tissues. Another phosphorus-containing lipoid, lecithin, is found in the protoplasm of the cell and has important functions in absorption of nourishment and elimination of waste In the vitally important nucleus are granules of chromatin, a complex protein that contains iron and is essential to the life of the cell, iron is also present in cytochrome in the protoplasm, which is essential to the oxidative processes of the tissues by means of which their life is sustained Sulfur is a constituent of two amino acids (cystine and methionine) that are built into tissue proteins,

Figure 48. [illegible]

Chemistry.)

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[3] Sherman, H C., CHEMISTRY OF FOOD AND NUTRITION, p 229 Macmillan, 8th ed., 1952.

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Figure 48 Skeletons of two albino rats showing [illegible]

as well as of substances (vitamin B_1 or thiamine, glutathione, etc) that function in oxidation-reduction processes, which in turn set free energy for life processes of cells Inorganic salts that contain sodium, potassium, calcium, magnesium, sulfur, phosphorus, and chlorine are also constant and important constituents of protoplasm of cells in the blood and soft tissues. Potassium salts are especially abundant in soft tissues, whereas sodium salts predominate in the body fluids.

The red corpuscles of the blood are special cells developed to carry oxygen to the tissues and remove the carbon dioxide that results from combustion of body fuel. Their ability to perform these functions depends on their content of the iron-containing protein, hemoglobin. Over 60 per cent of the body's total iron content is concentrated in the hemoglobin in red cells of the blood Although the importance of the functions of hemoglobin cannot be overestimated, it should be remembered that the relatively small quantities of iron distributed elsewhere in the body (in chromatin, iron-containing enzymes in muscle, etc) are also of vital importance

3 *Fluid tissues* of the body are the blood plasma, lymph and interstitial fluids surrounding the cells These body fluids consist chiefly of water, carrying dissolved proteins and *inorganic salts*. Sodium chloride is by far the most abundant of the mineral constituents of the blood, but salts of practically all the more common mineral elements are also found in the body fluids Mineral salts, when in solution in water, dissociate into charged ions, and the influence of and balance between the different ions is chiefly responsible for the action of body fluids in regulating certain body processes, as will be described later. The mineral salts in blood plasma also aid in keeping proteins in solution and furnish material for the digestive secretions that are secreted into the alimentary tract—chlorine for hydrochloric acid in the gastric juice, and sodium for sodium salts that create an alkaline reaction in the intestinal juices.

Mineral Deficiencies

Deficiency of any mineral element may occur whenever the demand in the body exceeds the supply in food, whenever assimilation from food is unusually poor, or whenever extra large amounts are lost from the body. Such deficiencies will be more serious and will show up more quickly during the growth period or during pregnancy and lactation, when the quantities needed are larger. Even in normal adults, small amounts of mineral elements are constantly excreted from the body, chiefly as salts in the urine, and these losses must be made up by the mineral elements taken in food if the body is not to become depleted As the amounts of these substances which must be supplied daily are relatively small, the results of a diet deficient in mineral salts will not be apparent so quickly as the results of a diet deficient in energy or in quantity or quality of protein.

If mineral deficiencies occur during the growth period, growth will be stunted, if they occur during pregnancy, the offspring may be stillborn or too weak to survive for long Those tissues that have a special need for certain elements will naturally be the first to show the effects of an insufficient supply of the particular elements, e g , bones and teeth will suffer first from a lack of calcium or phosphorus, the red blood corpuscles (hemoglobin) from a lack of iron, and the thyroid gland from a lack of iodine Prolonged lack of or excessive drainage from the body of any mineral element may result in serious symptoms of disturbed conditions in the body For instance, potassium deficiency has been shown to occur after prolonged infusions of glucose and sodium chloride solutions into the blood or after increased losses of this element in the stools during diarrhea Such potassium deficiency may manifest itself by disorientation, increased irritability, and other nervous symptoms, and by decided muscular weakness

The ordinary mixed diet will supply plenty of most of the mineral elements needed for upkeep of body tissues Sodium and chlorine are furnished abundantly by salts in foods and by table salt (sodium chloride) added to the food When heat has caused profuse perspiration, with excessive loss of sodium chloride through the skin, the taking of

Figure 49 Destructive changes in jaw and teeth of guinea pig caused by prolonged mineral deficiencies in the diet (Courtesy of Dr Percy R Howe, Forsyth Dental Infirmary, Boston, Mass)

extra salt in food or drinking water may help avert weakness and symptoms such as are seen in heat prostration. The need of the body for sulfur will be met if its protein needs are supplied, since most proteins contain sulfur. A diet adequate as to energy, protein, calcium, and iron will supply ample phosphorus. Potassium is a constituent of many foods, and is especially abundant in vegetable foods. Most of the mineral elements that are needed in very small amounts are widely distributed in foods, especially in unrefined plant foods.

The special problems of how to get sufficient quantities of calcium, iron, and iodine will be taken up in detail in Chapters [illegible] and 9. The special needs and diets for children and pregnant women will likewise be treated in later chapters.

MINERAL SALTS AS BODY REGULATORS

Exchange of Body Fluids

It is easier for most people to realize that tissues cannot be built without *the mineral elements which are essential parts of those tissues* than it is to understand why mineral salts are necessary to the normal functioning of the body. The ways in which mineral salts act as *body regulators,* listed in the lower half of Table [illegible] (p. 123), require fuller explanation.

Perhaps the most familiar of these regulating actions of salts is the relation between the salt content of the tissues and of the fluids which come in contact with them, in determining the amount of water which will be held back in the tissues or given up to the surrounding fluid. *Movements of water into or out of the tissues* are largely controlled by this factor. If the salt content of the tissues gets a little too high, water will pass from the surrounding fluid into the tissues to dilute the salt to its normal concentration, whereas if the salt concentration in the surrounding fluid is greater than it is in the tissues, water will be drawn out of the tissues. The absorption of water from the alimentary tract, the passage of water from the blood stream into the tissues or from the tis- [illegible] from the body through the [illegible] [illegible]e of fluids is at least par- [illegible] present on the two sides of some body membrane.

Since the salts in the circulating fluids of the body (blood, lymph, and interstitial fluids) are chiefly those of sodium, *low-sodium diets* have received much attention for use in cases of high blood pressure (hypertension), and even for weight reduction. If sodium content of the blood is high, water drawn in from the tissues or held in blood to dilute it to nearer normal salt concentration will mean larger blood volume, hence higher blood pressure and greater burden on the heart. An additional

complication in cases of high blood pressure is damage to the kidneys, so that they are unable to excrete salts in normal quantities If the sodium chloride (common salt) intake is not kept down to fairly low level, water may be held back in the tissues to dilute the retained salt, this may easily lead to dropsical swelling and increased body weight Conversely, low-sodium diets may result in excretion of extra sodium formerly retained in the body, hence loss of accumulated water from the body and reduction in body weight Although moderate restriction of salt in the diet ■ a wise precaution for many older people and its more drastic limitation may be needed in some cases of hypertension, *excessively* low-sodium diets often cause lack of appetite and they may also be low in some other essential nutrients Their use is seldom advised unless necessary in treating a diseased condition and then, if possible, not over too long a period Obviously their use solely to effect weight reduction is ineffectual, since loss of body water means only temporary reduction in weight and permanent weight reduction will be brought about only by reduction of caloric intake with resultant burning of body fat

Normal Functioning of Muscles and Nerves

We are not usually conscious of the part salts play in the exchange of body fluids unless conditions become abnormal, and the same is true of their role in maintaining the ***normal irritability of the nervous tissues and contractility of muscular tissues.*** Neither muscles nor nerves will function properly unless they are bathed in tissue fluids which contain a certain amount of salts and have the proper balance between the different mineral elements Calcium salts seem to have a stimulating effect, which tends to counterbalance the more or less relaxing or depressing effects of the salts of magnesium, sodium, and potassium Too much calcium salts in the blood may cause a state of tonic contraction of the muscles (rigor), while a spasmodic state of muscular tremors, called ***tetany,*** results when the calcium content of the blood gets below a certain amount Ordinarily the content of the different salts in the blood and tissue fluids is regulated (chiefly by hormones) to ■ nice balance and a constant level so that the muscles and nerves function normally The rhythmic alternate contractions and relaxations of the heart muscle constitute an example of this regulation, and are dependent upon the maintenance of a normal concentration of all the necessary mineral salts in the blood

Blood Clotting

It should also be noted that the presence of calcium salts in the blood is necessary to its clotting The ***clotting of blood*** is ■ protective arrangement to prevent undue loss of blood through cuts or hemorrhages Persons whose blood does not clot as readily as it should and whose

blood calcium is low are given doses of calcium salts in preparation for an operation. But delayed clotting or inability of blood to clot may be caused by lack of some other essential factor (such as the enzyme prothrombin), so that it may also occur in persons with normal blood calcium

Oxidations in Tissues

The essential part which the elements iron and iodine play in the *oxidative processes* of the body has been stressed in earlier sections. In discussing iron as a building material (p 126), it was pointed out that oxidation in the tissues could not go on at all except for the ability of the iron-containing hemoglobin to transport fresh supplies of oxygen to the tissues, while chromatin and other iron-containing enzymes are essential to bring about oxidations within the cells. In connection with basal metabolism (p. 46), emphasis was given to the fact that the iodine-containing hormone secreted by the thyroid gland has such a decided effect in speeding up the *rate* of oxidative processes in the tissues as to be a major, if not the chief, factor in determining the rate of basal metabolism. Thus both of these elements are vital for normal tissue oxidations, which in turn are essential to the life of body cells.

Maintenance of Body Neutrality: Mineral Elements in Acid-Base Balance

Here again we have a regulatory process in which mineral elements participate that is essential to the welfare of the body The cells and enzymes in the tissues function best in a neutral or faintly alkaline medium, and will be unable to function if the reaction within the cells or in fluids surrounding the cells differs too widely from the "optimum" reaction. Hence, there are elaborate mechanisms for keeping the blood and tissue fluids at just about a neutral reaction. We have already mentioned (p. 96) that proteins in the blood play a part in regulating its neutral reaction by acting as "buffer" substances, capable of uniting with either acids or bases in such a way as to prevent their affecting blood neutrality. Mineral elements also participate in regulating body neutrality, in that some of them give rise in metabolism to acidic and others to basic substances, and these two types of substances can be paired off together to form neutral substances called salts

The mineral elements may be classified as to their acid- or base-forming properties, as follows.

Acid-forming elements	*Base-forming elements*
Sulfur	Sodium
Phosphorus	Potassium
Chlorine	Calcium
	Magnesium
	Iron

When sulfur is taken in proteins and phosphorus in proteins or other organic phosphorus-containing compounds, these elements are oxidized to sulfuric and phosphoric acids in metabolism. Likewise, carbon is oxidized to carbon dioxide whenever organic compounds are burned as body fuel, and this in turn unites with water to form carbonic acid. These three acids, especially carbonic acid, are constantly being formed in tissue metabolism and must be neutralized by basic substances to form salts. Chlorine, although an acid-forming element, is taken into the body almost entirely in the form of salts, chiefly common salt or sodium chloride. Salts taken in food can yield no energy, are used in small amounts for tissue upkeep, but all excess amounts of them are excreted by the kidneys. Carbonic acid is kept from accumulating in the body by the fact that excess amounts of carbon dioxide are carried in union with hemoglobin to the lungs, where it is "ventilated off" in expired air.

Many basic elements are present in foods in organic combinations the organic part of which can be burned up, leaving the basic element free to combine with or neutralize acids and form salts. For instance, most of the calcium in milk exists as a salt of the protein casein (calcium caseinate), much of the basic elements in fruits is present as salts of organic acids, such as citric and malic acids (e.g., sodium citrate in oranges, potassium malate in apples), and much of the iron in meats is in combination in organic compounds. The protein, organic acids, or other organic matter is oxidized or burned up in metabolism (to yield carbon dioxide and water), leaving the basic elements free to combine with acids taken in food or formed in metabolism. Thus it is advantageous if the acid-forming and base-forming elements in the diet approximately balance each other, as in this way the maintenance of body neutrality will be favored.

Foods may be classified as to whether they are acid-forming or base-forming, that is, whether they will furnish a preponderance of acid-forming or base-forming elements after the organic part of the food is burned up or oxidized in the tissues. The acid-forming foods usually are high in protein (which carries sulfur and phosphorus) or contain both starch and protein (cereal foods), the vegetable foods are base-forming because they contain a preponderance of basic elements, either as inorganic salts or as salts of organic acids that can be burned in the body.

Acid-forming foods	*Base-forming foods*
Eggs	Most fruits
Meat, fish, and poultry	Vegetables (esp. legumes and white potatoes)
Breads of all kinds	Nuts
Cereals, pastries, puddings, etc.	Milk

The maintenance of neutrality in the blood and tissues, however, is too important a matter to be left solely to chance selection of diet, in fact, it is of such vital concern that the body has a first, second, and a

third line of defense against excessive acidity or alkalinity. Many persons eat principally meats and cereal foods, with scanty amounts of fruits and vegetables, and apparently suffer no harm. Although there is no doubt but that eating generous quantities of fruits and vegetables is a practice that makes for health in the long run, these foods supply vitamins and fiber along with base-forming elements and their beneficial effects may be due to a combination of all these factors. No matter how unbalanced the diet may be between acid-forming and base-forming foods, the development of a true "acidosis" or "alkalosis" is not permitted to occur under normal circumstances because supplementary ways of regulating body neutrality are called into play.

The three-way system of *protecting body neutrality,* in which mineral elements participate but are not solely relied on, may be briefly described as follows.

1. Proteins and salts of phosphorus- and carbon-containing acids (phosphates and carbonates) act as buffer substances in the blood and tissues, which means that considerable amounts of either acid or alkali can be taken up by them in such a way that the neutral reaction remains unaffected.

2. The body has a reserve acid, carbonic acid, which can be made from the normal products of tissue metabolism, carbon dioxide and water. When larger amounts of basic elements must be taken care of, some of the carbon dioxide that would otherwise leave the body through the lungs is conserved to be used to make salts of carbonic acid (carbonates) by union with sodium, potassium, or other basic elements.

3. The body similarly has in reserve a base that it can resort to in emergency, namely, ammonia, which may be formed by the kidneys in time of need. Thus if there has been excess production of acids in metabolism (e.g., sulfuric and phosphoric acids from overeating of protein foods), some ammonia may be called upon to link up with acids in ammonium salts, which leave the body in the urine.

The body normally maintains a certain store of basic elements, known as the "alkali reserve." The chief disadvantage of ingestion of too much acid-forming foods or of formation of too great amounts of acids in metabolism is not in danger of blood or tissues actually becoming acid, but in the fact that under these conditions the excess acid will have to be neutralized by drawing on the "alkali reserve" and that the body store of base-forming elements may become depleted. When base-forming foods predominate in the diet, not only is there no need to draw on the "alkali reserve," but this reserve of basic elements is built up to a point where *it is at least* a safeguard for the tissues and *may* be a factor in promoting health.

WATER

Water Losses

The fact that the water content of the body must be replenished from without to make up for continuous loss of this substance is a matter of such common knowledge that we need not dwell on it here Water is excreted from the body by the kidneys in the urine, by the lungs as water vapor in the expired air, and by the skin as sensible or insensible perspiration Lesser amounts are regularly lost in the stools The relative amounts which are excreted through these different channels vary somewhat, as is well known Ordinarily more water is excreted in the urine than by other channels, but in hot weather a larger amount is thrown off in perspiration in the effort to regulate the body temperature (see page 54) and a smaller volume of more concentrated urine is secreted. The amount lost through all channels averages 2 to 2½ quarts per day

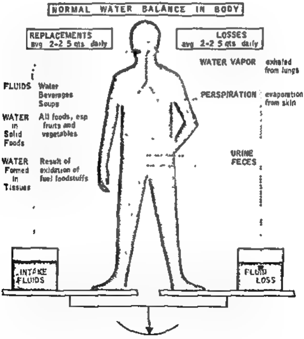

Figure 50 Normally the intake and output of water from the body are approx-

if the body stores of water are not to be depleted

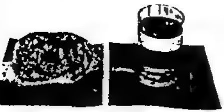

Figure 51 Amount of water in a half-pound potato (Taylor and MacLeod, Rose's FOUNDATIONS OF NUTRITION, Macmillan Co)

Water Replacements

This loss must be made up by the water furnished from three different sources, namely,

(1) By the fluids taken (water, beverages, soup, etc.);
(2) By the water contained in solid foods,
(3) By the water produced in the body as a result of the metabolic processes

Solid *foods* contain a good deal of water—ranging from about 5 per cent in very dry foods like crackers to over 90 per cent in juicy fruits and vegetables like tomatoes, eggplant, cauliflower, lettuce, strawberries, and watermelon. Even such a solid food as bread contains water to the extent of about 35 per cent of its weight.

Also many people do not realize that we form water in our own *tissues* as a product of the oxidative processes which are necessary to sustain life *(see Chapter 18, on metabolic processes)* Water is always one of the products formed when fuel foods are burned in the tissues to get energy, and thus so-called "metabolic water" may amount to about a pint per day

However, in addition to the water obtained from these two sources, [illegible]

good deal of [illegible] as large an amount of water as this but, within reasonable limits, an excess of water intake over the actual need is a good thing Taking too large an amount of water throws an unnecessary burden on the kidneys in getting rid of the excess There is no objection to drinking water with meals, provided the amount taken is moderate and it is not used to wash down the food. A moderate amount of water taken with or preceding a meal is an aid to digestion, since it promotes the secretion of gastric juice in the stomach. Large quantities of an iced beverage, however,

slow down digestion and are harmful. Unless it is exceptionally hard, hard water is usually not injurious, but mineral waters may be harmful and should be taken only on advice of a physician.

Suggestions for Water-drinking

One glass on rising	1
One glass before (or during) each meal	3
One glass in middle of forenoon	1
One glass in middle of afternoon	1
	6

Water as a Body Regulator

The *functions* of water in promoting body processes are chiefly based on its usefulness as a *solvent.* Most of the body materials except bone, skin, cartilage, and fatty substances will dissolve in it Since chemical reactions between substances cannot take place unless they are in solution, the materials of which the cells are made must be kept in solution in order that their life processes can go on In fact the protoplasm of most cells consists of approximately three-fourths water, e g, muscle tissue contains 70 per cent water (p 92).

Water is also useful in keeping substances in solution in the gland secretions, circulating fluids, and excretions It helps to promote the flow of *digestive juices* and dilutes the food taken The digestive juices contain much water, most of which is reabsorbed from the intestine and used over again in the body Soluble products of digestion are absorbed along with the water About ten pounds of water in the *blood* is in use constantly to carry soluble nutrients to the tissues and waste products to the kidneys for excretion *Urine* consists of 96 per cent water and 4 per cent solids, which have to be held in solution in order to be flushed out of the body

One of the most conspicuous regulating activities of water is its role in *regulating body temperature.* It equalizes temperature by transporting heat from one part to another in circulating fluids Its evaporation from the skin and lungs offers one of the best ways of getting rid of unwanted heat generated in the body

Water as a Tissue-Building Material

Water is also, strictly speaking, a tissue-building material, even though it does not furnish any energy to the body This is because water is a prominent and essential constituent of every kind of tissue, from a solid tissue like bone which is one-third water to a fluid tissue such as whole blood which consists of four-fifths water About 100 pounds of a 150-pound man's weight is due to the water content of his body. One can see how necessary it is for growth and tissue upkeep that water be provided regularly.

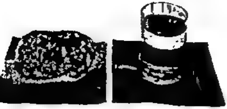

Figure 51 · Amount of water in a half-pound potato (Taylor and MacLeod, Rose's FOUNDATIONS OF NUTRITION, Macmillan Co)

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However, in addition to the water obtained from these two sources,

excess of water *intake over the actual need is a good thing. Taking too* large an amount of water throws an unnecessary burden on the kidneys in getting rid of the excess. There is no objection to drinking water with meals, provided the amount taken is moderate and it is not used to wash down the food. A moderate amount of water taken with or preceding a meal is an aid to digestion, since it promotes the secretion of gastric juice in the stomach. Large quantities of an iced beverage, however,

the bulk of material is sufficient to cause active peristalsis in this portion of the bowel.

In addition to having sufficient bulk for the intestine to work on, it *is necessary to maintain the **tone** of the intestinal muscles* and *to have* sufficient *moisture* and mucus present in the intestine to lubricate the passage of the feces Although the ingestion of considerable fiber is important, it is not the only factor that must be taken into account in order to avoid constipation (see page 402).

How To Get Fiber

Fiber is best obtained as an *integral part of foods* It is better to get cellulose in the form of *fruits, vegetables,* and *whole grain* foods than it is to take substances like bran or agar-agar either separately or mixed with the food In some instances the latter procedure may be necessary for short periods as a corrective measure, but adding *bran* regularly to a diet already rich in high residue foods is like "carrying coals to Newcastle" and may result in irritation of the intestine If fruits, vegetables, and thoroughly cooked whole-grain preparations are given a prominent place in the diet, there will be no danger of a lack of indigestible residue in the intestine Typical low-residue and high-residue foods are shown in the following lists.

Low-Residue Foods	*High-Residue Foods*
Sugar	Fruits (esp if eaten with skins)
White bread	Vegetables (except potato)
Highly milled breakfast cereals, e g, cream of wheat, white farina, etc	Whole wheat bread
Meat	Breakfast cereals from whole grains, e g, oatmeal, shredded wheat, dark farina, etc
Potato	
Fats	
Milk	

QUESTIONS AND PROBLEMS

1. Name ten mineral elements that must be supplied to the body in the food Which two of these are furnished in proteins? Which two are needed in largest quantities, and why? Which two are needed only in very small amounts but play an important part in facilitating oxidation in the tissues? Explain how these two elements function in tissue oxidations

2 Why are mineral elements necessary for the building and upkeep of tissues? How does the quota needed for growth compare in amount with that required for maintenance in the adult? Cite the conditions that may appear as the result of an insufficient supply in the diet in the case of each of the following elements calcium, phosphorus, iron, copper, iodine At what periods of life will a deficiency of mineral elements be most likely to occur, and why?

3 Name five ways in which the mineral elements act as regulators

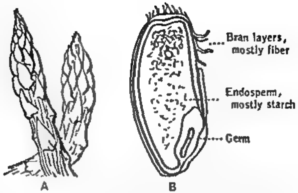

Figure 52. Fiber in foods *A*, softer type of fiber as found in young, tender vegetables such as asparagus tips, *B*, cross section of wheat grain showing the harsher type of fiber (bran) in the outer layers of the grain The outer layers and germ are removed in highly milled flour and cereals

FIBER

Vegetable *fiber*, or *cellulose*, is not a food material but it may be said to have a regulatory function in the diet. Since the human digestive tract is unable to digest and absorb cellulose, this substance can be of no use to the body as a whole However, it is desirable, and indeed practically necessary, to have some indigestible residue left behind in the alimentary tract after the food substances are absorbed, and for this purpose it is essential that a suitable amount of cellulose or fiber be taken along with the food materials.

Cellulose, or *vegetable fiber*, should not be confused with *animal fiber*, such as is found in meats The latter consists chiefly of collagen, a protein-like substance which can be converted into gelatin, digested and absorbed Hence, for indigestible fiber we have to turn to plant foods This fiber is supplied chiefly in fruits, vegetables, and the outer coats of grains (see Fig. 52)

Need for Fiber

Carbohydrates, proteins and fats are usually 90–98 per cent digested and absorbed, and the absorption of mineral salts and water is also fairly complete under favorable circumstances. If it were not for the indigestible substances *taken in food, the bulk of material in the lower part of the* intestine would be so small that there would be little *stimulus to the intestinal muscles* to move the residue along and procure evacuation of the lower bowel frequently enough to make for intestinal hygiene and the proper excretion of those waste products thrown off by way of the intestine Moreover, the more active muscular contractions (peristalsis) of the upper intestine, which are stimulated by the presence of a considerable bulk of food, make for better absorption Food residues do not have a chance to collect, stagnate, and putrefy in the lower intestine, when

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of body processes, and explain in each case how they function to bring about their regulating effects.

4. Name four "trace" elements needed in human nutrition. Explain why each is essential and how it functions in the body. In what way is fluorine of special interest for dental health?

5. What proportion of each of the following tissues consists of water: blood, muscle, bone? Is water necessary for building and maintaining tissues? Name and discuss three ways in which water acts as a regulator of body processes.

6. By what routes is water lost from the body? What conditions determine the relative amounts of water lost through the skin and in the urine? What conditions make for excessive loss of water from the body? What is the normal loss of water from the body daily (approximate)? Name three sources from which the body receives water to make good this loss. What is meant by water balance, and why is it important?

7. Why is vegetable fiber needed in the diet? Describe the effects of a diet that supplies too little fiber, of one that supplies too much fiber or a harsh fiber that is irritating to a sensitive intestine. What foods are lacking in fiber and what types of foods furnish fiber abundantly?

8. It has been estimated that normal adults require 4–7 gm. fiber per day in order to secure daily bowel movements. Given the following figures for fiber in foods, arrange a combination of foods that would introduce about 6 gm. fiber into the diet.

	Fiber, gm		Fiber, gm
Apple, 1 small	1.0	Beets, ½ c. diced	0.9
Banana, 1 medium	0.6	Beet greens, ½ c. cooked	1.4
Raspberries, ½ c. canned	2.4	String beans, ¾ c. cooked	1.4
Prunes, 4–5 medium	0.7	Carrots, ¾ c. cubed	1.1
Strawberries, ½ c. fresh	1.2	Peas, ¾ c. fresh, green	2.2
Whole wheat bread, 3 slices	1.0	Oatmeal, ¾ c. cooked	0.3
White bread, 4 slices	0.3	1 shredded wheat biscuit	0.6
		Cream of wheat, ½ c. cooked	0.1

9. Keep a record of your total intake of water for one day, that is, the amount taken as water, soup, tea, coffee, and milk. How does your intake compare with the amount that most persons should take either in *beverages or as drinking water?*

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Calcium and Phosphorus

There is two to three times as much calcium and phosphorus in the body as all the rest of the mineral elements combined, since they make up so large a proportion of the bones, the structural framework of the body Because they are so closely associated in the formation and upkeep of the ***bones and teeth,*** these two elements may conveniently be considered together

Although most of the calcium and phosphorus in the body is concentrated in the bones and teeth, it should be remembered that the smaller amounts of these elements in the blood and tissue fluids have important individual functions that make them essential for the welfare of the body as a whole In addition to their participation in the general functions of inorganic salts (see page 123), most of their special functions were discussed in Chapter 7 However, it may be well to recapitulate briefly here the ***special functions of calcium and phosphorus*** (other than their use in bones)

Calcium in blood plasma is one of the essential factors for blood clotting, it markedly affects muscle tone and irritability, the proper balance between calcium on the one hand, and sodium, potassium, and

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end of the bone. Within the cavity, the blood vessels come in contact with the mineral material in the trabeculae, so that it may be readily taken up in the blood stream to meet minor fluctuations in blood calcium. The more abundant the supply of calcium in the food, the greater will be the development of bone trabeculae, when the diet has been deficient in calcium, these structures may be practically absent (see Figure 53). Sherman has said, "Thus extra calcium received by the body is not only 'passively' stored It also adds itself to the body's 'working capital' of blood- and tissue-regulating material"[1]

Calcium and phosphorus in the digested food material is absorbed through the intestinal wall and carried in more soluble forms in the blood to all parts of the body, so that various tissues can withdraw amounts needed (and contribute mineral elements discarded by tissue cells) Any excess quantities of these two elements are excreted in part into fecal material in the *intestine* and in part as soluble salts in the *urine* The relative amounts that leave the body by one route or the other vary with numerous conditions The feces contain both some calcium and phosphorus that was not absorbed from the food, along with some that has been metabolized and excreted

Maintenance Requirement and Standard Allowance for Adults

Since calcium and phosphorus are continually being lost to the body by excretion in urine and feces, sufficient amounts should be taken in foods at least to balance these losses. The quantities needed are determined by balance experiments similar to those described for nitrogen balance (p 97) The calcium and phosphorus content of the food intake is compared with the sum of all calcium and phosphorus lost to the body in the urine and as unabsorbed or excreted minerals in the feces In 1920, Sherman examined all the balance experiments then available and placed the average *minimum requirements* at 0 45 gm calcium and 0 88 gm phosphorus daily for a man of average weight Mineral requirements

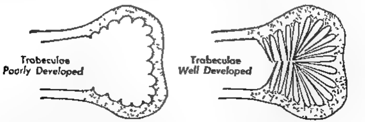


Figure 53 Diagrammatic representations of bone trabeculae showing poor or good development according as the food-calcium intake is low or liberal (Sherman, H C Chemistry of Food and Nutrition, The Macmillan Co, 1952)

[1] Sherman, H C., Chemistry of Food and Nutrition, p 263, Macmillan, 8th ed, 1952

magnesium on the other, is necessary for normal rhythmic contraction and relaxation of the heart. Regulation of the blood calcium to a normal level is an important function of the parathyroid glands.

Phosphorus is an essential constituent of protein in nuclei of all cells, as well as of phospholipids, fatlike substances that play an important role in metabolism. Phosphoric acid is indispensable to the oxidation of carbohydrate by which most of the energy for body processes is obtained, it links with glycogen and sugar to activate them for oxidation, and is a part of several enzymes that are essential to this oxidation. Inorganic phosphates in the blood act as "buffer substances" that assist in maintaining blood neutrality and the acid-base balance of the body (see page 130).

In discussing the quantitative needs for calcium and phosphorus in this chapter, we shall see that by far the largest part of our intake of these two elements is used for the building and upkeep of bones. However, it should not be forgotten that the less conspicuous uses of these elements are equally important and may be responsible to a considerable extent for their influence in promoting physical well-being.

Metabolism and Excretion

The "turn-over" of mineral elements in metabolism is much slower than that of carbohydrates, fats, and proteins. It has been estimated that there is a daily exchange of about ⅓ of 1 per cent of the protein in the body, as against ⅛ of 1 per cent of the phosphorus and $^1/_{30}$ of 1 per cent of the calcium. The metabolism of such tissues as bones and teeth is especially slow, and formerly the calcium phosphate stored in these tissues was thought of chiefly as inert material, which to some extent constituted *reserve stores* of calcium and phosphorus but which would be drawn on only in case of great need. Now the store of these two elements in the bones, especially that in the ends of bones (epiphyses), has been shown to be much more readily available for use in the body than was formerly thought. Radioactive (tagged) phosphorus and calcium, when injected as salts, are found to be deposited promptly in bone, given up gradually to the blood plasma, and excreted over long periods (almost entirely in the urine). The teeth take up little of these substances, and none is found in tooth enamel. The very slow metabolism of the tooth structure in adults probably accounts for the fact that, once the teeth are laid down and calcified, their composition is difficult to alter by changes in diet.

The more "labile" supply of calcium and phosphorus in bones is found in the trabeculae, which are crystals of calcium compounds growing from the inner surface of the cavity at the bone's end, projecting toward the center in such a way as to act as braces in strengthening the

The allowance for phosphorus was formerly given as 1.32 grams per adult per day, but in the most recent recommendations of the Food and Nutrition Board no allowances for phosphorus are included. This is because experience has shown that diets which meet the recommended levels for protein, calcium, and iron are practically certain to provide plenty of phosphorus. For discussions in this chapter, typical foods that are good sources of phosphorus are listed in Table 9 (p. 150). It should be noted that foods that are depended on to furnish protein, calcium, and iron (such as meats, milk and its products, whole grain cereals, leafy vegetables, etc.) are mostly among those which supply phosphorus liberally. The intake of phosphorus should be about 1½ times that of calcium, which for the average adult would amount to approximately 1.2 grams per day; such a level of intake is ordinarily not difficult to attain.

Allowances during Childhood, Pregnancy, and Lactation

Adults need calcium and phosphorus only for maintenance of a body already built, but children need also a "growth quota." Extra amounts of these elements are required not only for the *growth* of bones but also for their *strengthening* by further deposits of calcium phosphate. The bones of a newborn infant are more flexible and of lower mineral content than those of an adult, undoubtedly a provision of nature to make birth easier. As the child grows, the relative proportion of calcium phosphate in the bones should be increased, so that they will become stronger and more rigid, in order to bear the weight of the body and to be less easily broken. Per unit of weight, growing children may need two to four times as much calcium as does an adult. Children will go on growing on diets that supply less than desirable amounts of calcium and/or phosphorus, but the bones and teeth will not be of as good quality, or growth may not be so rapid as with a more liberal allowance of these elements; if the quantity of either element is too limited, growth may be stunted. At levels of 1 to 1.5 grams daily of each of these elements in the diet, children have been found to show "maximum retention," i.e., as much calcium and phosphorus is provided as the body can store.

Women in the latter half of pregnancy and those who are nursing their babies have considerably higher calcium and phosphorus needs than do normal adults, since the mineral needs of the growing fetus or infant must be met through the mother's body. For mothers, as well as for growing children, there should also be a plentiful supply of vitamin D, a vitamin that helps assure good absorption and assimilation of the mineral elements provided in the diet. A liberal intake of calcium is especially important during lactation, in order to provide for the secretion of calcium-rich milk without undue drain on the reserve stores of calcium in the mother's own body. Specific allowances for children of different ages, and for pregnant and lactating women, will be found in Chapters 24 and 25, devoted to diet for these conditions.

vary *slightly* with body weight but are uninfluenced by muscular activity.

Since 1920 a much larger number of balance experiments have been made and tend to indicate that the calcium requirement (1) is *higher* than at first thought and (2) *varies* fairly widely among different individuals. Leitch[2] and Owen[3] concluded that, irrespective of body weight, the maintenance requirement of adults is about 0.55 or 0.52 gm. calcium per day. Still later experiments[4] of Chu, Outhouse, Steggerda and Mitchell show a calcium requirement of 7 to 7.5 milligrams per kilogram body weight, or an approximate range of 0.5 to 0.7 grams daily for the normal adult.

Some recent studies[5] have brought out the ability of men to adapt, with time, to lower calcium intakes and to maintain calcium balance on intakes as low as 200 to 400 mg. daily. Although it is true that a higher proportion of calcium is utilized on a low intake than when it is liberally supplied, most of the national groups cited as in equilibrium on such low calcium intakes either live in tropical or semi-tropical areas (where abundant sunlight favors calcium utilization by forming vitamin D in the body) or may have hitherto unrecognized sources of calcium in the diet (such as the lime-steeped corn used for making tortillas in Mexico, or the "stone powder," which is essentially calcium carbonate, added to rice during its milling in Formosa). In a review of the extensive literature on calcium balance experiments,[6] Ohlson states, "Few adults eating diets characteristic of our society are in equilibrium on intakes of less than 500 mg. (0.5 gm.) per day."

The Food and Nutrition Board of the National Research Council in 1958 set its recommendation for a *standard allowance* of calcium at 0.8 gram per day. This allowance is supposed to provide a "factor of safety" above the bare maintenance requirement and to cover individual differences in need or in ability to utilize calcium in the diet. Despite their lesser weight, the same amount is recommended for women as for men, in order to cover menstrual losses and to provide a reserve store in the body to meet needs of pregnancy and lactation. The balance of opinion is that intakes of 0.8 gm. daily are generous (many adults will remain in excellent nutrition on 0.5 gm.) but that occasional individuals may need the higher allowance and the excess (if any) will do no harm.

[illegible] that extra liberal supplies of [illegible], there is no evidence as yet

[2] Leitch, I., Nutr. Abst. & Rev., 6, 553, 1937, and ibid. 8, 1, 1938.

[3] Owen, E. C., Biochem. J., 33, 22, 1939.

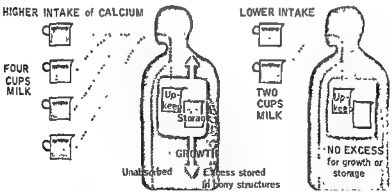
[4] Chu, H. I., *et al.*, Chinese Med. J., 59, 1, 1941, Chem. Abst., 35, 5163, 1941. Outhouse, J., *et al.*, J. Nutr., 21, 565, 1941; Steggerda, F. R., and Mitchell, H. H., J. Nutr., 31, 407, 1946.

[illegible]

tion" of these elements, and other vitamins (especially A and C) probably also influence calcium absorption favorably in a lesser degree The influence of vitamins on mineral metabolism will be taken up more fully in later chapters With so many factors involved, it is not hard to understand why the absorption of these two mineral elements varies rather widely in different individuals or in the same individual from time to time. Especially in the case of calcium, which tends to occur often in *relatively insoluble forms, it is not difficult to appreciate that much of* that provided in the diet may never really become available to the body

The relative amounts of the absorbed calcium and phosphorus that will be ***retained*** in the body will also vary, depending on the *age* of the person, his ***previous dietary*** habits, the ***level of the current supply,*** and other factors The quantity of the mineral element retained by or lost from the body is determined by balance experiments (amount in food minus total in urine and feces), a negative balance prevails when outgo exceeds intake, but a positive balance indicates retention of the given element in the body With adults the amount ingested should be at least *sufficient to equal the amount lost from the body (equilibrium), but with* growing children there should be enough calcium and phosphorus in the *diet to provide for adequate storage of these elements in the body*

Growing ***children*** will naturally store more of these elements than adults, since they are building new bone, muscle, and nerve tissue, and in addition the bones need to be built up to a higher content of calcium and phosphorus to strengthen them When these two elements are pro-



Utilization: Absorption and Retention in the Body

Utilization is the general term used to indicate the relative amount of a nutrient in the food that the body is able to absorb and to make use of, the amounts retained in the body may be used either for current upkeep of the tissues or to build up body stores.

One reason that the allowances for calcium and phosphorus have to be set as high as they are, in order to assure enough for body needs, is that their absorption from the intestine is variable and often far from complete. These two elements may occur in foods either in the form of mineral salts or in complex combinations in organic foodstuffs; in the latter instance the organic foodstuffs must be digested before the mineral elements are set free for absorption. Then the mineral elements must be present in some soluble form in order to pass through the intestinal lining and thus be taken into the body proper. The relative insolubility of calcium phosphate, which makes this salt so useful for strengthening of bones, militates against its absorption from the contents of the intestinal tract.

Since the salts formed by calcium and phosphorus are most readily soluble in solutions that are slightly acid, the *acid reaction*, which commonly prevails in the contents of the upper *intestine* due to the acidity of the digestive fluid secreted in the stomach, is *favorable* for their absorption, conversely, conditions are less favorable for their absorption in the lower part of the intestine where the digestive fluids secreted are alkaline in reaction Any factor that renders the intestinal contents more *alkaline*, or that causes precipitation of calcium or phosphorus in *insoluble* form, will be *unfavorable* and lower the absorption of these elements. For instance, large amounts of fat in the diet may result in poor absorption of calcium through formation of insoluble compounds of calcium with fatty acids (insoluble calcium soaps), and large doses of iron salts will lower phosphorus absorption because insoluble combinations of iron and phosphorus are formed in the intestinal contents. Most of the phosphorus in grains exists in the form of a complex salt called *phytin* and ordinarily a good part of it becomes available for absorption after digestion of the food, but if there is an excess of calcium in the intestinal contents, it may form calcium phytate, an insoluble salt, and thus lower absorption of both these mineral elements.

Large amounts of *fiber* in the diet, *laxatives*, or emotional upsets—in fact, anything that increases frequency of bowel movements—will tend to produce poor absorption of calcium and phosphorus (or of any nutrient) because food is hurried through the intestine too quickly for absorption to be completed. The *ratio of calcium to phosphorus* in the diet also affects their absorption, since either element is poorly utilized in the presence of relatively large amounts of the other, better utilization takes place when they are furnished by the diet in nearly equal amounts. A liberal supply of *vitamin D* acts in some way to increase "net absorp-

speculate on whether this may not be indicative of a habit of taking less than "optimum" amounts of these mineral elements in the diet. However, decalcification of the bones in old age may be caused by several factors other than diet (such as change in ductless gland activity) in which case the supply of dietary calcium and phosphorus would be only a secondary factor. At any rate, the same allowance as for younger adults should be maintained for the aged, if possible.

Foods as Sources of Calcium and Phosphorus

In planning a diet that will furnish enough calcium and phosphorus (or other mineral elements) to meet body needs, one must take into account three main factors:

(1) How much of the mineral element is present in different foods,
(2) What foods furnish it in well utilized condition,
(3) Which of the foods are rich enough in it or can be eaten in sufficient quantity to provide the daily quota.

In Table 9 (p. 150), these factors have been taken into consideration in order to make apparent which foods will contribute most to the calcium and phosphorus of the average dietary. Typical foods that are excellent or good sources of these two elements are listed. The first column of figures under each mineral element gives the amount furnished in an *average serving* of each food in the condition in which it is eaten (cooked or raw), the second column shows the number of milligrams present in 100 grams of the food substance. Thus, cheddar cheese is by far the richest of any food listed for calcium but, because an average serving is only 1 ounce, one glass (8 oz.) of milk will furnish more calcium than a serving of cheese. Milk, which is 87 per cent water, is not so high in calcium and phosphorus as dried beans or dried figs, but comes at or near the top of the list for both elements in amount furnished in an average serving. Dried fruits ordinarily are eaten in small quantities and dried beans increase in water content on cooking.

CALCIUM. The only really *rich* food sources of calcium are milk and its products (other than butter), including cheeses, ice cream, and light cream, and certain of the green leafy vegetables (those in which calcium is present in assimilable form). Broccoli, legumes, and dried fruits are also good sources of calcium, other fruits and vegetables all contain smaller amounts of calcium but must be consumed in considerable bulk in order to add much of the element to the diet. Among the fresh fruits, oranges and figs are highest in calcium content. Eggs and nuts (which are high in phosphorus) are of only moderate calcium content, while meat and grains are calcium-poor.

PHOSPHORUS. Phosphorus is associated chiefly with protein-rich foods and cereal products. It is found in many foods that contribute little calcium, as well as along with calcium in milk and its products. Rich sources of phosphorus in the diet are meats (especially organs), fish,

vided liberally and in right proportions in the diet, more of them will be absorbed into the blood stream, and hence their storage in the body will be favored In series of balance experiments on children from three to thirteen years of age, Sherman and Hawley[7] showed that, although positive calcium balances could be obtained on as low an intake as 0 4–0 46 gm per day, it required an average daily intake of about 1 0 gm. of calcium to induce a nutritionally desirable rate of storage of this element, increasing calcium intake above this level produced little further increase in the amount retained. When each child received (in addition to a normal mixed diet) 750 gm. (a little over ¾ quart) of milk daily, there was an average daily storage of 0 01 gm. calcium and 0 008 gm phosphorus per kilogram of body weight, but individual children varied widely in mineral retention, apparently depending on previous feeding. Those whose previous calcium intake had been low, and whose bodies were presumably relatively calcium-poor, showed far higher levels of calcium retention on the improved diet. Those whose bodies were already well stocked with calcium showed a lesser tendency to store this element[8] These facts have been amply confirmed by later investigators, especially Daniels and her colleagues.[9] Outhouse and co-workers[10] found difficulty in securing retention by children of any more than 20 per cent (one-fifth) of the calcium in the diet, but Stearns and Jeans[11] reported higher percentages retained by a large proportion of the children studied. Perhaps the average utilization of food calcium is about 33 per cent (one-third) There may also be seasonal variations in the amount of calcium stored by children, since there is a tendency for growth to be more rapid at certain times of the year.

In *adults* (with the exception of pregnant women) mineral retention is relatively small, perhaps about one-tenth that of childhood. Again retention varies with individuals, with level of the calcium and phosphorus intake, and with previous level of feeding of these elements. Attention should be called to the fact that teen-agers and young adults (16 to 22 years) should be storing calcium and phosphorus at a rate less than children but greater than mature adults (from 3 to 6 times more than the average adult), so that the level of these mineral elements in the diet should be high during these years

Physicians have recently been commenting on the frequency with which x-ray photographs show rarefied bones in older adults, and they

[7] Sherman, H C, and Hawley, E, "Calcium and Phosphorus Metabolism in Childhood," J Biol Chem 53, 375, 1922

[8] [illegible]

J. Nutr, 10, [illegible]

[10] Outhouse, J, *et al*, J Nutr, 23, 1, 1942

[11] Stearns, G, and Jeans, P. C, "Utilization of Calcium Salts by Children," Proc. Soc Exper Biol & Med, 32, 428, 1934, for later discussion of calcium and phosphorus needs of children see Stearns, G, J A M A, 142, 478, 1950.

and poultry, eggs, cheeses and milk, nuts, legumes, and all foods made from grains (especially whole grains). Fruits (especially dried ones) and vegetables contribute lesser amounts of phosphorus to the diet. In general, edible roots, stems, and flowerets of plants contain similar amounts of both calcium and phosphorus, but plants concentrate calcium in the green leaves and phosphorus in the seeds (grains) The darker green leaves have higher calcium content than light green ones (inner leaves of head lettuce)

It will be seen that phosphorus is carried in foods more liberally than is calcium, and many foods that provide little calcium (such as meats) are excellent sources of phosphorus Since its distribution follows that of protein, a diet that supplies adequate amounts of protein will usually be adequate for phosphorus, if the diet also provides the standard allowances of calcium and iron, it will almost certainly be adequate in phosphorus This explains why we do not have to calculate the phosphorus content of the diet when we know that the quotas for protein, calcium, and iron are met

How to Get the Standard Allowance of Calcium in the Diet

It is by no means easy to provide for adults the standard allowance of 0 8 gram of calcium per day, indeed, without fairly liberal use of milk and its products it is almost impossible In order to avoid decimals,

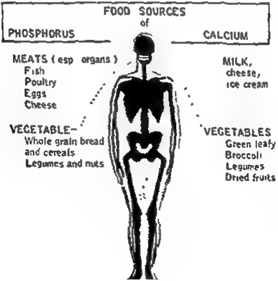


Table 9. Foods Richest in Calcium and Phosphorus

Calcium, in Milligrams		
Food	*Per Avg Svg*	*Per 100 gm*
Milk, 8 oz glass, ½ pt	288	118
Cheese, Am cheddar, 1 oz	206	725
*Leafy vegetables, *avg* ½ cup cooked	200	200
Broccoli, 1 lg stalk	130	130
Ice cream, plain, *avg* ⅙ quart	123	123
†Molasses, med , 2 tbsp	116	290
Cream, light, 7 tbsp	97	97
Baked beans, canned, with molasses, ½ cup	73	56
without molasses, ⅔ c	53	41
‡Cottage cheese, 2 rd tbsp	54	96
Figs, dried, 2 small	56	186
canned, 3, w/juice	35	35
Orange, 1 medium	48	48
Parsnips, ½ c cooked	44	57
String beans, ¾ c , ck	33	36
Orange juice, 6 oz	35	19
Egg, 1 medium	26	54
Peas, canned, ½ c	26	32
Lima beans, ½ c , ck	23	29
Apricots, dried, ck , 4 halves	24	24
Dates, 3–4, pitted (1 oz)	22	72
Peanut butter, 2 tbsp sc	22	74
Grapefruit, ½ small	22	22
Salad greens, raw, *avg* 2 lg or 4–5 sm leaves	20	40
Bread, w w , 1 slice	22	96
white, 1 slice (4% milk solids)	18	79
Prunes, 4–5 medium, ck	17	25
Cereal, whole grain, *avg* ½–¾ c , cooked	8–15	9

Phosphorus, in Milligrams		
Food	*Per Avg. Svg*	*Per 100 gm*
Liver, fried, 2 sl. (74 gm)	311	358
Milk, 8 oz glass, ½ pint	227	93
Cod steak or sole (100 gm)	220	220
Lamb, leg, roast, 2 sl (75 gm.)	194	257
Beef, rib roast, 3 sl. (90 gm)	167	185
hamburger, 1 lg (82 gm)	145	158
Baked beans, canned, ½ c.	147	113
Cheese, Am cheddar, 1 oz.	140	495
Peanut butter, 2 tbsp sc	118	393
Shredded wheat, 1 biscuit	102	360
Whole wheat cereal, ⅔–¾ c , cooked	113	83
Oatmeal, ⅔ c , cooked	105	67
Cottage cheese, 2 rd tbsp	108	189
Egg, 1 medium	101	210
Ice cream, plain, *avg.* ⅙ quart	99	99
Cream, light, 7 tbsp	77	77
Broccoli, 1 lg stalk	76	76
Nuts, mixed, 8–12 nuts (½ oz)	67	446
Parsnips, ½ c., cooked	62	80
Lima beans, ½ c , ck.	62	77
Peas, canned, ½ c	62	77
Corn, canned, ⅓ c.	43	52
Cauliflower, ½ c , ck	42	72
Leafy vegetables, ½ c ck , avg	45	45
Bread, w w., 1 slice	60	263
white, 1 slice (4% milk solids)	21	98
Apricots, dried, ck , 4 halves	34	34
Figs, dried, 2 small	33	111
canned, 3, w/juice	21	35
Prunes, 4–5 medium, ck	27	40
Dates, 3–4, pitted (1 oz)	18	60
Orange, 1 medium	23	23
String beans, ¾ c , ck	19	23
Grapefruit, ½ small	18	18

* ... beet greens, and chard, in which calcium is in nonutilizable ... collards, and kale

† ... alic acid in refining sugar, it is in lowest ... in the "blackstrap" variety

‡ Calcium content of cottage cheese varies according to whether it is made from sour milk or by addition of rennin to sweet milk

oxalate-containing leafy vegetables might combine with calcium in other foods and thus rob the body of otherwise available calcium, seems to have been an unjustified "bogey" Remington and Smith[12] found that spinach, fed in relatively enormous amounts to rats, had no bad effects on growth or bone formation, Kohman[13] concurred in the conclusion that oxalates in spinach have no effect on bone growth, provided the diet includes other foods that carry adequate available calcium

Suggestions have been made of reinforcing the calcium content of some staple food or foods In the case of white bread, this has been done by addition of milk solids in amounts of 2 to 6 per cent, making the calcium content of white bread (but not the phosphorus content) almost equal to that of whole wheat bread Supplementary sources of calcium that have been suggested include calcium salts (carbonate or phosphate) mixed with salt, the enrichment of meat with calcium from bone by cooking with the bone in water acidified with vinegar, or addition of steamed bone meal or alfalfa ash to certain foods None of these practices have any wide use in this country at present

The inclusion of at least a pint of milk daily in the diet of adults is urged as the chief means for obtaining the calcium quota, as well as for the high quality proteins and vitamins that milk provides For those who do not drink milk it should be incorporated in cooked foods, and the more common use of cheese would also be advantageous Hard cheeses have much higher calcium content than soft cheeses with higher water content, cottage cheese has only about one-seventh as much calcium as a hard cheese like cheddar (American), but ½ cup of it will take the place of a scant half cup of milk in calcium value The wider use of green leafy vegetables (including salad greens) would help to reinforce the diet in calcium, as well as in other minerals and vitamins

Effects of Dietary Deficiencies of Calcium and Phosphorus

In the United States, where dairy products and meats are freely available, symptoms of any dietary deficiency of either calcium or phosphorus are seldom seen among *adults* True, many adults may have bones and teeth of poorer quality than would have been the case if these bone-building elements had been furnished in larger quantities during the earlier years of their life, and many may have less than optimum body "stores" of these elements (in the bones, especially the trabeculae) available to draw upon in case of emergencies However, there are no symptoms by which we may detect such border-line deficiencies Dietary surveys show that few persons take diets that provide less than the standard allowance of phosphorus, but many freely chosen diets fall below the level of calcium intake recommended in the standard allowance This does not prove that actual calcium deficiency is of frequent

[12] Remington and Smith, Science, 101, 272, 1945
[13] Kohman, Science, 101, 610, 1945

Foods That Furnish Adult Standard Calcium Allowance

(0.8 gm. or 800 mg. daily)

(1)	Calcium, mg	(2)	Calcium, mg	(3)	Calcium, mg	(4)	Calcium, mg
Milk, 1½ pts.	864	Milk, 1 pint	576	Milk, ½ pt.	288	Cheese, Am. ched., 1½ oz.	309
		Cottage cheese, 2 rd. tbsp.	54	Cheese, Am. ched., 1 oz.	206	Ice cream, plain, ⅛ qt.	123
		Bread, w. w., 4 slices	88	Bread, w. w., 4 slices	88	Bread, w. w., 4 slices	88
		Orange, 1 med.	48	Orange juice, 8 oz.	48	Turnip greens, ½ c., ck.	188
		Green beans, ¾ c., ck.	33	Broccoli, avg. svg.	130	Beans, baked, with molasses, ½ cup	73
				Cream, light, 3 tbsp.	45	Egg, 1 med.	26
			799		805		807

the figures for calcium content of foods in Table 9 (p. 150) are given in milligrams, the student should remember that it requires 800 milligrams to make 0.8 gram. Below are given four groups of foods, each group furnishing the standard calcium allowance for a day, with decreasing amounts of milk in the diet, it should be noted how many other foods that are good or fair sources of calcium are needed as a supplement.

Of course, other foods in the average diet contribute minor amounts of calcium. For instance, an average serving of most vegetables (exclusive of leafy ones and broccoli) will furnish 20 to 60 mg. calcium, and a serving of fresh or canned fruit from 10 to 20 mg.; thus two servings each of fruit and vegetables might contribute somewhere in the neighborhood of 80 to 120 mg. calcium. Although this is some help, one can see that some concentrated sources of calcium are needed in fairly large amount to build up the quota of 800 mg., or 0.8 gram.

It is also important to consider which foods carry calcium in forms that are readily absorbed from the intestine and hence *available for use* in the body. The relative utilization of calcium from different foods has been established by experiments too numerous to cite. The calcium in milk is that best utilized by man and its availability is not altered by pasteurization. Broccoli, cauliflower, and kale rank almost with milk in availability of their calcium content, while that in carrots, lettuce, string beans, and almonds has been shown to be only slightly less well assimilated. Leafy vegetable with fairly well utilized calcium include kale, cabbage, collards, turnip greens, and probably also mustard and dandelion greens. Spinach and other leafy vegetables of the "goosefoot family," including chard and beet greens, have calcium in insoluble combination with the oxalic acid which these leaves contain, and hence in a form totally unavailable to the body. However, the fear formerly felt that

oxalate-containing leafy vegetables might combine with calcium in other foods and thus rob the body of otherwise available calcium, seems to have been an unjustified "bogey" Remington and Smith[12] found that spinach, fed in relatively enormous amounts to rats, had no bad effects on growth or bone formation, Kohman[13] concurred in the conclusion that oxalates in spinach have no effect on bone growth, provided the diet includes other foods that carry adequate available calcium

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[13] Kohman, Science, 101, 610, 1945

Figure 56 Two puppies of the same age The larger one had an abundant supply of milk, the smaller one had little milk but plenty of other food In addition, the larger had been allowed to run about exposed to sunshine while the smaller was kept in a kennel (Courtesy of Shattuck Farms, Andover, Mass)

occurrence, since the standard allowance has purposefully been made liberal to allow for individual differences in utilization of food calcium and in body needs While a few people may need more than the standard allowance, many can get along perfectly well on less than this amount (their minimum requirement will be met by smaller quantities). It may well be true that a higher level of calcium intake (especially if supplied by milk which also reinforces the diet in other minerals, protein, and vitamins) would provide a factor of safety and even be conducive to better health, but the amounts of calcium (and phosphorus) actually required for body upkeep in adults are not very large.

In *children or young animals,* who need calcium and phosphorus in relatively large amounts for building bones and teeth, an insufficient supply of either element or both will produce effects that are readily seen or otherwise demonstrated. The effects of such deficiencies during the growth period may be manifested in one or more of the following ways:

(1) by stunting of growth,
(2) by poor quality of bones and teeth,
(3) by malformations of the bones

Figure 56 shows the stunting of growth in a puppy which received plenty of other food but little milk, in this instance there was lack of

calcium and phosphorus in the diet, as well as lack of vitamin D which makes for better utilization of these elements (no sunshine) Figure 57 shows subsequent good growth of this dog when the diet had been changed to include plenty of milk, but the handicap of a narrow chest cavity with limited breathing capacity remains as a result of the deficiency in earlier life When calcium lack has not been too severe, no effect may be noted in the size of the body but the bones may be either delicate and brittle, or remain soft and pliable because too little mineral salts are deposited in them The skeleton of the smaller rat in Figure 48 (p 125) shows both stunting in size of bones and their poor quality as exemplified in brittleness and certain deformities The child suffering from rickets shown in Figure 58 evidences the bone deformities peculiar to that disease—narrow chest, enlargement of bones at their ends (seen at knees), and bow-legs resulting from inability of soft bones to bear up the body weight This disease, caused by lack of either calcium, phosphorus, or vitamin D, will be treated more fully after discussion of vitamin D The bone deformities of rickets may persist in later life, the narrow chest being a predisposing factor in the development of tuberculosis and the narrow pelvic cavity being a complicating factor in event of pregnancy

The *teeth* are largely formed during the latter part of fetal life and during infancy Any lack of calcium or phosphorus during this period is

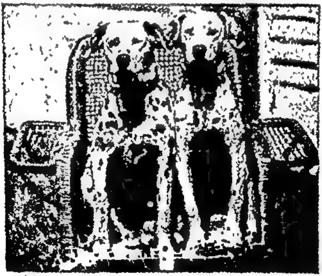

Figure 5? ·
which interval bot ... at the
right is the one w ... ates inability to
recover completely ... of material for bone-building
(Courtesy of Shatt ... Mass)

Figure 58 › Rachitic child—note bow-legs with enlargement of bones about joints, deformity of chest and enlargement of abdomen (Morse, CLINICAL PEDIATRICS)

likely to result in malformed teeth and jaws, or in poor quality teeth that are more subject to decay in later life. Doubtless many instances of poor quality teeth or of teeth crowded too closely in a narrow jaw are due to the fact that the mother received an insufficient supply of calcium, phosphorus, or other dietary essentials during pregnancy or to the fact that the child received an insufficient supply of them during its first years of life It is difficult, by good diet in later life, to undo the effects of such deficiencies during the formative period. The bones of a woman may also suffer during pregnancy or lactation, if a lack of calcium in her diet compels the maternal organism to draw on its own bony structures for the mineral elements needed to supply the child. Figure 59 shows examples of the effects on the facial bones and teeth resulting from severe and prolonged deficiency of calcium and phosphorus in the diet, contrasted with children whose diets had supplied these elements liberally

In parts of the world where food supplies and living conditions are less favorable than in the United States, conditions that indicate calcium or phosphorus deficiency may be found more frequently both in children and in adults. When milk and meats are scarce or unavailable, a large proportion of the diet must come from vegetable sources, especially cereal grains Even whole grains are of low calcium content and much of their phosphorus is in the form of phytin, we have seen that much of the phosphorus held in this organic combination is not only unavailable for absorption into the body but may form insoluble compounds with calcium, rendering some of it unavailable. Hence, stunting of growth and abnormalities of bones and teeth may be common in children. In India, especially among women kept in "purdah" (confined

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within doors), a disease called *osteomalacia* is common, it is characterized by inadequate calcification of the bones, usually due to a combined deficiency of calcium and of vitamin D (brought about by lack of sunlight) *Osteoporosis*, a disorder in which there is thinning and decalcification of bone already laid down, is fairly common among older people even in this country, although it *may* be partially arrested by giving more liberal amounts of calcium,[14] it is questionable whether it is due primarily or solely to lack of sufficient calcium Phosphorus deficiency sometimes occurs in cattle grazing on soil that has been depleted of phosphates (by crops, leaching, etc), since the grass grown on such soil will be of low phosphorus content, such a deficiency is evidenced by decrease or distortion of appetite (desire to eat bones, wood, etc.), emaciation, weakness, and eventually death. Phosphorus deficiency has not been seen to any real extent in humans.

QUESTIONS AND PROBLEMS

1 In what special tissue or tissues is most of the calcium and phosphorus in the body found? What function do they serve in this tissue? In what other tissues do these mineral elements occur, and what are the special uses for them, other than those named above?

2. Can the body build up reserve stores of calcium and phosphorus, provided the diet supplies more than enough to meet current body needs? Where are these elements stored? What are the bone trabeculae and what is the advantage of having them well developed?

3. Why do growing children store more calcium and phosphorus than adults? In addition to their rate of growth, what other factors will influence the relative amount of the calcium intake that will be retained in the body? What special advantages are there in a liberal intake of both calcium and phosphorus for young children? Why are the needs for these two elements higher in pregnant women and nursing mothers than in other adults?

4 By what route or routes are the calcium and phosphorus that are not retained in the body excreted? What is meant by calcium or phosphorus balance, and how are they determined? What condition is indicated by a negative balance, by a positive balance?

5 Give the minimum requirement and recommended allowance for calcium in normal adults Why does the Food and Nutrition Board not set a standard allowance for phosphorus? Explain why the minimum requirement for calcium varies rather widely in different individuals Why is the standard allowance for calcium set as high as it is?

6. Compare the average extent to which calcium in the food is utilized with the degree of utilization of proteins, fats, and carbohydrates in foods. Why is the absorption of mineral elements less complete?

[14] Owen, E C, Irving, J T, and Lyall, A, "The Calcium Requirements of Older Male Subjects with Special Reference to the Genesis of Senile Osteoporosis," Nutr Abst. & Rev, 10, 134, 1940

Name three factors that have a favorable influence and three that have an unfavorable influence on absorption of calcium from the intestinal contents What vitamin exerts an important influence on the utilization of calcium and phosphorus?

7 Name the two classes of foods that are the richest sources of calcium, of phosphorus Name five specific foods that are comparatively rich in calcium and five rich in phosphorus Which foods are used in large enough quantities in the average diet to contribute largely in making up the calcium quota for the day? Which classes of food contribute phosphorus liberally but carry little calcium? Why is the average diet less likely to be high in calcium than in phosphorus?

* 8 Make a record of all the foods eaten in a certain day, with the quantities of each consumed Using either Table 9 (p 150) or the table in the Appendix which gives nutritive values of average servings or common measures of foods, calculate the quantity of calcium furnished by this day's diet (either in milligrams or grams) How does the total compare with the standard allowance for calcium? If it is lower than the standard, how could it best be reinforced as to its calcium content?

*9 Calculate the amount of calcium that would be supplied by the following group of foods, recommended to form the basis of the daily diet for an adult

Milk, 1 pint
Meat, fish, or poultry, 1 serving
1 egg
1 svg other protein food
(meat dish, legume, nuts, or cheese)
Vegetables, 2 svgs—one green or yellow
Potato, 1 svg
Fruits, 2 svgs—one citrus or tomato
Whole grain or enriched bread or
cereal, at least 2 svgs
Butter or margarine, at least two svgs

What foods could you add for extra energy that would increase the calcium intake?

10 What symptoms may develop in growing children as the result of a deficient supply of calcium and/or phosphorus in the diet? Why do adults seldom show recognizable signs of such deficiency? What signs of deficiency may appear in adults after long-continued diets that furnish too little calcium for body needs? At what periods in life is the character of the teeth most affected by any deficiency in these mineral elements?

* It is suggested that half the class work out question 8 and the other half question 9

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Iron, Copper, Cobalt, and Iodine

All of these elements are needed in very small amounts for upkeep of the body—only about one-tenth as much iron is needed as calcium or phosphorus and one-tenth as much copper as iron, while iodine and cobalt are required in even smaller quantities. Yet these elements are extremely important for body welfare and play interesting roles in metabolism.

IRON

Distribution and Uses in the Body

As calcium and phosphorus are concentrated in the bones, so iron [illegible]

the blood, which is about twenty times as rich in iron as the average of other tissues. In the red blood cells the chief solid constituent is the pigment hemoglobin, and iron is an essential constituent of hemoglobin in

amount of about one-third of one per cent of the large protein molecule The next largest concentration of iron is that stored in the liver, spleen and bone marrow, which normally constitutes 30–35 per cent of that in the whole body

The minor quantities of iron (about 10 per cent) found in other tissues are nevertheless vitally important as is evidenced by the localities where they exist, as listed below.

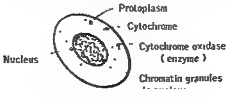
(1) in chromatin granules in cell nuclei,
(2) in cytochrome (pigment) in protoplasm of cells, and in numerous enzymes that help catalyze oxidation-reduction processes in body tissues,
(3) in muscle hemoglobin (myoglobulin), which is closely related in chemistry and function to blood hemoglobin but is fixed in muscle tissues

In all of these sites (see Fig 60), the iron-containing compounds are involved in the life processes of cells and tissues

Iron owes its usefulness in the body to its special ability to be alternately oxidized and reduced, i e, to take on oxygen and later give this oxygen up to other substances By means of this property, the iron-containing hemoglobin in red blood cells is enabled to take on extra oxygen when blood circulates through the lungs, to carry oxygen to the tissues, and there to pass it on to the tissue cells for oxidative processes necessary to their life Venous blood, which owes its bluish color to the presence of reduced hemoglobin, takes on excess carbon dioxide (a waste product of tissues) and is returned to the lungs, where it loses carbon dioxide and takes on another load of oxygen, becoming bright red again when oxyhemoglobin is formed The iron-containing pigments and enzymes in the tissues serve to bring about transfers of oxygen within cells in much the same manner, cytochromes and cytochrome oxidases (enzymes) have been estimated by Schultze to be responsible for about 90 per cent of the energy transfers associated with the oxidative phases of tissue respiration

Absorption and Metabolism

Iron is thus a very precious element to the body, which absorbs it with difficulty from foods but uses its stores of this element over and over again, and normally excretes only very small quantities Since the



body's iron is thus conserved, the daily need for replacement is small (only a few milligrams). However, the amount carried in foods is likewise small, and experiments[1] have shown that healthy human adults usually *absorb less than one-tenth of the iron in the foods fed*

The relative amount absorbed from the intestine seems to *vary according to the need of the body* for iron, in growing children,[2] pregnant women,[3] and persons whose body stores of iron have been depleted by previous iron deficiency,[4] much larger amounts are absorbed than in adults whose diet has been adequate to keep up normal body stores of iron The fact that iron absorption is in some way controlled by the need of the body for iron has received much study and one of the current theories is that a specific protein in the intestinal mucosa is able to combine with iron and act as a carrier.[5] This protein is called apoferritin and its compound with iron is ferritin If there is need for extra iron in the body (as evidenced by low blood serum level), apoferritin can pick up iron from the intestinal contents and pass it into the blood Removal of iron from the protein complex, for current use or to replenish body stores, will set free apoferritin, which can be used again to further iron absorption When the protein is already saturated with iron, no more of this element is absorbed

Although the main factor is thus the need of the body for a fresh supply of iron, several other factors are known to exert an influence, favorable or adverse, on the absorption of this element. Both inorganic and organic iron can be utilized, but *iron is more readily absorbed in the less oxidized form*—as ferrous rather than ferric iron Factors favorable for absorption are normal acidity of the gastric juice secreted in the stomach, enough bile for good digestion of fats, an otherwise well balanced diet (calcium and certain vitamins seem to influence absorption favorably, while an excess of phosphorus will form insoluble iron compounds), and the presence of iron in readily absorbable forms Phytin, found especially in grains, militates against absorption by forming insoluble compounds with iron, as with calcium. Intestinal putrefaction also tends to precipitate iron in insoluble form, and diarrhea (as occurs in sprue, colitis, etc) will naturally result in poor absorption

The metabolism of iron closely parallels that of red blood cells, since a major portion of it is used for making hemoglobin in these cells Among the billions of red blood cells (about 4½ to 5 million per cubic centi-

[1] Moore, C V, and Dubach, R, "Absorption of Iron from Foods Tagged with Radioiron," Tr A Am Physicians, 64, 245, 1951

[2] Darby, W J, *et al*, "Absorption of Radioactive Iron by Children 7–10 Years of Age," J Nutr, 33, 107, 1947

[3] Hahn, P F, *et al*, "Iron Metabolism in Human Pregnancy as Studied with the Radioactive Isotope, Fe^{59}," Am J Obst & Gynec, 61, 477, 1951

[4] McCance, R A, and Widdowson, E M, Lancet, 2, 680, 1937, Hahn, Whipple, *et al*, J Exper Med, 70, 443, 1939, Hahn, P F, *et al*, Am J Physiol, 143, 191, 1945, Moore, Dubach, *et al*, J Clin. Invest, 23, 755, 1944.

[5] Granick, S, Physiol Rev, 31, 489, 1951

meter of blood), there are continual casualties and calls for replacements, the lifetime of such cells has been determined by "tagged" nitrogen to be about four months They are formed in the bone marrow and destroyed chiefly in the spleen. For their formation not only is iron needed but also protein (for the protein part of hemoglobin), and other materials for the "stroma," the body of the cell in which hemoglobin is embedded. When these cells disintegrate, the main non-protein portion of hemoglobin is split into an iron-containing substance (hematin) and a pigment (bilirubin), almost all of the iron and much of the bilirubin are saved to be used over again in new red corpuscles Practically no iron is excreted in the urine and the excreted iron lost to the body in the feces amounts ordinarily to less than one milligram daily.

Any excess of iron over and above current body needs, whether newly absorbed from food or part of the body's more permanent store, is stored chiefly in the liver, and to a lesser extent in the spleen, bone marrow, and kidneys, chiefly in the form of ferritin The body is said to have a store of readily available iron, a "labile pool of iron,"[6] made up of recently absorbed iron plus that recently released by the breaking down of red blood cells Older stores of iron (as in the liver) may be somewhat less readily available, and the "fixed" iron in tissue cells and iron-containing enzymes is not drawn upon even in times of great need for this element

Causes and Frequency of Iron Deficiencies: Anemias

Since the body uses iron so economically and has opportunity to build up considerable reserve stores of it over long periods, any deficiency due to an iron-poor diet or to poor absorption of the iron in the food will be likely to develop only after a long-period or under conditions where the need for iron is unusually high Hence, *nutritional anemia,* a condition where the hemoglobin in the red cells is abnormally low, is more likely to occur when the body has scant stores of iron due to long-continued iron-poor diet and when there is simultaneously an extra demand for iron, as in growth, pregnancy, or after loss of blood by hemorrhage

The *anemias* are conditions characterized either by reduction in the number of red blood cells or by less than normal amounts of hemoglobin in these cells In either case, the oxygen-carrying capacity of the blood is lowered, and symptoms of paleness, weakness, shortness of breath, lack of appetite, and general slowing-up of vital functions of the body are associated with this condition The existence of an anemia (and whether it is mild or severe) may be detected by "color index" of the blood, by counting and microscopic examination of the red blood cells, or by determination of the oxygen-carrying capacity of the blood A "blood count"

[6] Greenberg, G R, and Wintrobe, M M, "A Labile Pool of Iron," J Biol Chem, 165, 340, 1946

is usually part of any routine physical check-up Reams have been written in medical literature about the classification and the causes of different kinds of anemia. It is only necessary for us here to recognize three general classes of anemia, which differ in respect to whether or not they can be remedied by nutritional treatment.

Three distinct *types of anemia* are (1) that primarily due to deficiency of iron, (2) that due to excessive loss of blood, and (3) pernicious anemia, which has to do with lessened formation of the red blood cells rather than with lack of material to build hemoglobin

1 *Iron-deficiency anemia*, due solely to insufficient supply of iron in the diet, is seldom met with in adults, because of their small needs and the body's efficient use of iron, however, on diets that are not well supplied with iron, it may be precipitated by some other factor, such as poor utilization caused by diarrhea or subnormal acidity of the gastric juice (common in middle-aged women), or by excessive loss of blood at menstrual periods, from hemorrhoids, peptic ulcers, etc Lack of dietary iron is the most common cause of anemia that occurs in infancy, especially in infants fed on milk alone or on cereal gruels used in areas where milk is scarce The iron content of milk is low (although well utilized), but the infant comes into the world with an extra store of iron in its liver, usually enough to last about six months. Most infants are now given iron-rich foods well before they are six months old (egg yolk, chopped green vegetable and meat, etc) as insurance against the possible development of nutritional anemia The needs of the infant for iron are relatively high, because their blood volume is increasing and more hemoglobin is required to build a larger number of red blood cells Dr. Helen Mackay[7] made a study of the incidence of anemia in infants brought to the clinic in a poor section of London; although she set a rather low standard for normal hemoglobin concentration, among infants at five *months of age only 10 of the artificially fed infants and 16 of the breast-*fed infants out of every 100 examined came up to this standard. When given small doses of inorganic iron, these infants showed increased hemoglobin content of the blood as well as better health and weight gains The nutritional anemia of infancy is not so common in this country, but its prevention needs to be take into account in planning the diet of infants, especially of premature babies and twins, since these babies may be born with a poorer store of iron in their livers.

Nutritional anemia may also be precipitated in young girls, whose diet is on the borderline of adequacy for iron, when the onset of menstruation results in increased losses of iron from the body; the condition was formerly made worse by lack of exercise and outdoor life, which made for poor intestinal hygiene and poor utilization of iron Today, with better diets and more active outdoor life, the anemia of adolescence

[7] Mackay, H M M, *Nutritional Anemia in Infancy with Special Reference to Iron Deficiency*, Medical Research Council of Great Britain, Special Report Series No. 157, 1931.

(chlorosis) is far less common Pregnancy is another period during which such anemias are frequently seen, due to the increased need for iron both for blood in the unborn child and for building up a store of iron in its liver, the child may be born with a good store of iron in its own liver but this may be at the cost of depletion of the mother's stores Both in pregnancy and at middle age, there may be a decrease of stomach acidity, which induces poor utilization of food iron and is the predisposing factor for development of anemia Although this type of anemia may sometimes be induced simply by long-continued use of an iron-poor diet, more frequently the diet provides marginal amounts of iron and some condition that increases the iron need or makes for poorer utilization of dietary iron precipitates the development of anemia Such anemia yields readily to treatment with large doses of "medicinal" iron, but the diet and conditions that precipitated the anemia should also be improved

2 Anemias brought about by excessive *loss of blood* may also be treated by improving the diet, but such instances necessitate increases not only in iron but in all of the other substances required to build whole blood When the blood volume has been reduced by hemorrhage, water is rapidly drawn in from the tissues to restore its volume, but this diluted blood must then be replenished with plasma proteins, red cells, and hemoglobin New red cells are usually rebuilt more quickly than hemoglobin, so that for a time they carry less than normal amounts of this pigment (low color index) Hence the diet should provide a plentiful supply of all substances needed for rebuilding blood and especially of foods rich in iron content, medicinal iron is often given. Whipple and his associates[8] experimented extensively with hemoglobin regeneration in dogs rendered anemic by bleeding, they showed that the iron in some foods is better utilized for hemoglobin formation than that in others (liver, kidney, eggs, apricots, and raisins proved especially valuable) and that blood regeneration was markedly influenced by diet, high protein being particularly needed Leverton[9] studied blood regeneration in 129 young women who were blood donors, by supplementing their regular diet with protein, minerals, or vitamins On liberal protein intake (90 grams daily) other supplements were not required to give rapid regeneration, but with lower levels of protein increase of the iron, copper, or vitamin B_2 (riboflavin) intake hastened return of hemoglobin to normal levels Such studies emphasize the importance of a good all-around diet for recovery from hemorrhagic anemia, a diet especially rich in protein and including some rich sources of iron such as liver and other foods found valuable for hemoglobin regeneration by Whipple Hemorrhagic anemia is not

[8] Whipple, G H, "Hemoglobin Regeneration as Influenced by Diet and Other Factors," J A M A, 104, 791, 1935, Whipple, Miller, and Robscheit-Robbins, "Raiding of Body Protein To Form Plasma Protein and Hemoglobin," J Exper Med., 85, 277, 1947

[9] Leverton, R M, *et al*, "Blood Regeneration in Women Blood Donors Effects of Generous Amounts of Meat and Milk in the Diet," J Am Dietet. Assoc, 20, 747, 1944, and 'Effect of Protein, Vitamin, and Mineral Supplements," ibid, 24, 480, 1948

uncommon as the result of surgical operations, wounds, or peptic ulcer, or among persons who donate blood at too short intervals.

3 *Pernicious anemia* owes its origin not to lack of substances needed for hemoglobin formation (as in nutritional anemias) but to lack of some substance (or substances) required by the body for the production and development of the red corpuscles themselves (the body or stroma of these cells) The blood of pernicious anemia patients has a sufficiency of hemoglobin but a much lowered number of red corpuscles of varying size and shapes (some larger than normal). Another characteristic symptom in this disease is lowered secretion of gastric juice and below normal acidity of this secretion. Castle[10] put forward the theory that some factor (present in normal gastric juice) was lacking in gastric juice of pernicious anemia patients, a factor necessary for interacting with another substance furnished in foods and producing by the interaction the substance essential to production of red blood cells (intrinsic factor + extrinsic factor → erythrocyte maturation or anti-anemia factor). This anti-anemia factor acted to stimulate red cell formation in the bone marrow but was stored in the liver. The feeding of large amounts of liver was found to be effective in producing greater numbers of red cells, next the anti-anemia factor from liver was concentrated in extracts and injected or given by mouth along with stomach extracts, finally the pure substance, a small amount of reddish crystalline substance obtained from large quantities of liver, was isolated[11] and called vitamin B_{12} *Intramuscular injection of extremely small amounts of vitamin* B_{12} completely changes the blood picture in pernicious anemia, there is a rapid and spectacular rise in the number of red cells, and they are soon increased to normal values, at the same time, the other symptoms characteristic of the disease are relieved If vitamin B_{12} is given *by mouth*, normal gastric juice seems to be needed to promote its absorption from the intestinal tract It is now recognized that vitamin B_{12} is identical with the anti-anemia factor postulated by Castle, that it is usually provided in the diet in sufficient amounts, but that certain persons, who lack the "intrinsic factor" in gastric juice necessary for its proper absorption from the alimentary tract, will develop pernicious anemia due to lack of B_{12} in the body. Although no amount of iron by itself will relieve pernicious anemia, a good diet with plenty of proteins, minerals, and vitamins is considered a helpful adjunct to recovery.

To sum up—although the three types of anemia have different causes and only the nutritional type is due to a dietary supply of iron

[10] Castle, W B., "Present Status of the Etiology of Pernicious Anemia," Ann Int Med, 34, 1093, 1951.

[11] Vitamin B_{12} was isolated in 1948 simultaneously by Smith and Parker in England and Rickes, Brink, *et al*, in the United States As little as 1–5 micrograms injected intramuscularly daily will bring about a normal blood picture in pernicious anemia patients.

in insufficient amounts to meet body needs, the *diet* needed to help promote recovery is the same in each case Such a diet should be rich in iron and protein (basic materials for formation of hemoglobin), and should furnish plenty of other mineral elements and vitamins, which are helpful in ways not fully understood but seem chiefly to promote better utilization of iron

Requirement and Standard Allowance

Iron *balance*, i e, equality of intake and outgo, has been attained in adults on small amounts of iron in the daily diet, once the body has become adjusted to a low-iron diet Adults have been maintained in iron equilibrium on intakes ranging from 4 to 7 mg per day, or even less[12], this is not surprising when we consider how the body conserves its iron stores for reuse and actually loses very little of this element daily Moore,[13] from his studies using radioiron, estimates the total loss as 0 5 to 1 5 mg daily for full-grown men and for women after the menopause Younger women, who lose blood through menstruation, probably have an additional loss of body iron averaging 0 5 to 1 mg per day But pregnant women and growing children have higher iron needs, and it is desirable that the intake of iron be sufficient to allow for possible poor absorption and to keep up good iron reserves in the body

Moreover, one of the recent lessons of nutrition experiments is that utilization of iron is influenced by the nature of the diet in respect to other nutrients, i e, conditions are more favorable for iron absorption when the diet is well balanced with respect to calcium and phosphorus,[14] contains liberal vitamins,[15] and is adequate in other respects Leverton and Marsh[9] showed that of two groups of young women on almost the *same iron intake*, one group whose diet was otherwise superior maintained positive balance (were able to store iron), while the group with less adequate diet were in negative iron balance Moore and Durbach[16] point out that, if only 10 per cent of the ingested iron is absorbed, an intake of food iron of 12–15 milligrams per day would be necessary in order for the body to assimilate the amount which they consider necessary to maintain iron balance in adults

The *recommended allowances* of the Food and Nutrition Board at present are 10 mg per day for men and 12 mg for women, the slightly higher allowance for women, in conjunction with their lower body weight, should compensate for loss of iron through menstruation Some

[12] Farrer and Goldhamer, J Nutr, 10, 241, 1935, Leverton, J Nutr, 21, 617, 1941, Leverton and Marsh, J Nutr, 23, 229, 1942

[13] Moore, C V, Am J Clin Nutr, 3, 3, 1955

[14] Anderson, McDonough, and Elvehjem, "Relation of Dietary Calcium Phosphorus Ratio to Iron Assimilation," J Lab & Clin Med, 25, 464, 1940

[15] Fuhr, I, and Steenbock, H, "Effect of Dietary Calcium, Phosphorus and Vitamin D on the Utilization of Iron," J Biol Chem, 147, 59, 1943

[16] Moore, Durbach, *et al*, J Clin Invest, 23, 755, 1944

consider that these allowances are very liberal, providing for at least a 50 per cent surplus over actual needs; others (as Moore and Durbach) think they are none too high

Rapidly growing children need more liberal iron allowances than do normal adults, although the iron allowance of children 1–3 years of age is three times as large per pound of body weight as for adults, because of their small weight their total allowance is only slightly over half as large (7 mg). Adolescent boys and girls, along with women in the latter half of pregnancy and those who are nursing infants, have an iron allowance one-fourth higher than that of normal adults, namely 15 mg per day Standard allowances for children of various ages will be given in Chapter 25

Iron Content of Foods

Figures for the amount of iron in some typical foods, both in milligrams per 100 grams and in an average serving, are given in Table 10 (p 171) It will be evident that the quantity of iron in foods is much less than that of calcium and phosphorus, ranging from only 0 1 mg. in milk to 18 mg in raw pork liver, per 100 gm (3½ oz) of the food In many instances the distribution of iron follows that of other mineral elements, as it is relatively high in foods of low moisture content and low in fresh fruits and vegetables which contain large amounts of water and fiber. But milk, which is one of the best sources of calcium, is poor in iron, while organ meats like *liver* and kidneys are unusually rich in this element Other excellent sources of iron are *eggs, lean meats, legumes, nuts, dried fruits, whole grains* or enriched cereal foods, and *all* green, *leafy vegetables.* When eaten in large quantities, even foods of relatively low iron content, such as milk, fresh fruits, and most vegetables, may contribute considerable iron to the diet In general, colorless foods, such as highly milled cereals, white bread (unenriched), sugar and fats, are lacking in iron, and there is an old saying "White foods cannot make red blood"

The total amount of iron in a food does not necessarily mean that all of it will be available for use by the body Although the distinctions between inorganic and organic iron, as well as between ionizable and nonionizable iron, in foods are now considered of less importance than formerly, it is true that iron held in organic combinations, which must be digested before it can be absorbed, will be less completely available for body use if digestion is incomplete Also we have seen (pp 164 and 167) that numerous factors, such as nutrients in other foods taken in the diet and conditions in the alimentary tract, may influence the extent of iron absorption from a given food and hence its availability for hemoglobin formation, the body's main use for iron Whipple* experimented extensively with dogs rendered anemic by bleeding and kept on a standard diet, to which various types of food were added as sources of iron for

Table 10 Typical Foods as Sources of Iron

Food	*Size of serving*	*Iron, in milligrams* Per Avg Serving	*Iron, in milligrams* Per 100 Grams
Liver, calf, fried	2 slices (72 gm)	9 0	12 5
beef, fried.	2 slices (74 gm)	5 8	7 8
Meats (lean or med fat)			
Beef, round, ck	1 lg hamburger (82 gm)	2 7	3 4
rib roast, ck	3 slices (90 gm)	2 7	3 0
[illegible]	[illegible]	2 6	2 9
[illegible]	[illegible]	2 6	3 2
[illegible]	[illegible]	2 4	6 0
[illegible]			
pork and molasses	½ cup (130 gm)	2 7	2 1
with pork and tomato	½ cup (130 gm)	2 3	1 8
Eggs, whole	1 medium (54 gm)	1 3	2 7
Leafy vegetables			
Beet greens	½ cup, ck (100 gm)	3 2	3 2
Spinach	½ cup, ck (100 gm)	3 0	3 0
Chard	½ cup, ck (100 gm)	2 5	2 5
Turnip greens	½ cup, ck (100 gm)	2 4	2 4
Kale	½ cup, ck (100 gm)	2 2	2 2
Legumes, fresh			
Soy beans	⅔ cup, ck (100 gm)	2 8	2 8
Lima beans	½ cup, ck (80 gm)	1 4	1 7
Peas, green	½ cup, ck (80 gm)	1 5	1 9
Fruits, dried			
Peaches	3–4 halves, ck (100 gm)	1 8	dry, raw 6 9
Apricots	4 halves, ck (100 gm)	1 4	dry, raw 4 9
Prunes	4–5 medium, ck (100 gm)	1 3	dry, raw 3 9
Raisins	2 tbsp (20 gm)	0 6	dry, raw 3 0
Figs	2 small (30 gm)	0 9	dry, raw 3 0
Nuts			
Almonds	12–15 nuts (15 gm)	0 7	4 4
Pecans	12 halves, 2 tbsp chopped	0 4	2 4
Walnuts	8–12 halves, 2 tbsp chopped	[illegible] 3	2 1
Peanut butter	2 tbsp sc (30 gm)	0 6	1 9
Vegetables			
Broccoli	1 med lg stalk (100 gm)	1 3	1 3
Brussels sprouts	5–6 med (70 gm)	0 9	1 3
Cauliflower	½ cup, cooked (60 gm)	0 7	1 1
String beans	½ cup, cooked (62 gm)	0 45	1 1
Beets	2, 2 in diam (100 gm)	1 0	1 0
Carrots	½ cup, diced, ck (75 gm)	0 5	0 8
Potatoes, sweet	1 med, baked (120 gm)	1 1	0 9
white	1 med, baked (100 gm)	0 8	0 8
Cereals, whole grain			
Oats, flakes or meal	⅔–¾ cup, cooked (1 oz dry)	1 2	dry, raw 4 5
Wheat, flakes or meal	⅔–¾ cup, cooked (1 oz dry)	1 2	dry, raw 3 4
Farina, enriched (Quaker)	⅔–¾ cup, cooked (1 oz dry)	1 5	dry, raw 5 [illegible]
Bread, whole wheat	1 slice	0 5	2.2
white.	1 slice	0 15	0.6
white, enriched	1 slice	0 4	1.8
Fresh fruits and fruit vegetables	100 gm. serving, mostly	0 3-0 6	
Milk, whole, fluid	1 pint	0.35	0.1

hemoglobin regeneration. The results seem to indicate that the iron in organ meats, egg yolk, dried fruits, carrots, and potatoes is very completely utilized, while some of that in muscle meats, whole grains, and leafy vegetables is in less readily utilized forms. However, it is considered questionable whether the figures obtained under these conditions would apply to normal human beings on ordinary mixed diets. Balance studies on normal women conducted by Rose and associates[17] showed no differences in the utilization of the iron from egg yolk, whole grains, bran, lean beef, and peas, or inorganic iron in ferric citrate. Apparently, if the total iron content of the diet is sufficient to meet the standard allowance and if the diet is adequate in respect to other nutritive essentials, there is little need to worry about the special form in which it is provided in foods

How To Get Standard Allowance of Iron in the Diet

In the table below are given three groups of common foods, in average servings, which would furnish the daily iron allowance for an adult (12 mg) It will be apparent that if two or three servings of some relatively iron-rich foods are included, other normal items of the diet that provide minor amounts of iron will make up the desired total On days when liver is used, the total iron intake will probably be higher than the standard allowance, but the excess can be stored to make up for a day when a slightly less than normal amount is taken.

Foods That Furnish 12 Milligrams of Iron

(1)	*Iron, mg*	(2)	*Iron, mg*	(3)	*Iron, mg*
Hamburger, 1 lg (82 gm) ..	2 7	Pork chop, 1 med lg	2 6	Liver, calf, fried, 2 slices (72 gm)	9 0
Egg, 1 medium	1 3	Egg, 1 medium	1 3	Baked beans, canned, with pork and molasses, ½ cup	2 7
Beet greens, ½ c cooked .	3 2	Dried apricots or prunes, ck, svg	1 35	Milk, 1 pint	35
Beets, 2 small	1 0	Tomato, raw, 1 med	9		12 05
Potato, 1 medium	8	Peas green, canned, ½ c.	1 7		
Orange, 1 medium	6	Sweet potato, 1 med	1 1		
Banana, 1 medium	6	Bread, w. w, 3 slices	1 5		
Bread, w w, 3 slices	1 5	Oatmeal, ⅔–¾ c. ck	1 2		
Milk, 1 pint	35	Milk, 1 pint	35		
	12 05		12 00		

Since it is important, both for body welfare and for good utilization of iron, that the diet be adequate in all nutritive essentials, the groups of foods listed under (1) and (2) represent well balanced diets. If one follows the recommendation to include in the daily diet 1 pint of milk, 1 serving of meat, 1 egg, 3 or 4 slices of whole wheat or enriched bread,

[17] Vahlteich, Rose, *et al*, J Am Dietet Assoc, 2, 331, 1935, Houghton, D, "Utilization of Iron from Foods Studied by Two Methods," Thesis, Columbia Univ., 1942.

1 serving of potato, 2 servings of other vegetables (using colored and leafy ones fairly often), and 2 servings of fruit (one citrus or tomato), these foods alone will provide 9 to [illegible] mg of iron daily

Adequacy of American Diet as to Iron

Failure of the iron content of the diet to be adequate for actual body needs (especially in adults) is considered to occur infrequently now, provided most foods are taken in their natural state and not highly refined Several factors contribute to a greater feeling of confidence as to the adequacy of dietary iron under ordinary conditions First, the daily need for new supplies of iron has been shown to be smaller than was formerly thought, especially for adult men In addition, Americans are probably eating more green and leafy vegetables than they did formerly, whereas the consumption of meats remains high in spite of the high cost of these foods Lastly, the addition of iron to "enriched" white bread and "restored" highly milled cereals provides iron in staple foods which were formerly poor in it When cost limits the amount of meat and eggs used, greater dependence for iron will be placed upon legumes and cereals, so that the use of whole grain or enriched cereal products may mean the margin of safety in low-cost diets

Dietary surveys among women students in colleges in various parts of the United States showed iron intakes ranging from 8 8 to 21 8 mg daily, which indicates the adequacy of such diets Even though cereal foods occupy a less prominent place in the diet than formerly, the enrichment of white bread and highly milled cereals with iron compounds has meant an increase of iron in the average American diet Sherman and Lanford[18] give a table showing total iron in the average dietary, along with relative amounts furnished by different food groups, before and after the enrichment program was inaugurated The total iron intake rose from 13 6 mg per person per day (1935–39) to 17 1 mg (1952) and most of the additional iron was contributed by the bread and cereal group After grain products, meats, poultry, and fish furnished the next largest precentage of total iron, with fruits and vegetables in third place While these figures give assurance of the general adequacy of the American diet in respect to iron, *averages* may be misleading and doubtless there are many persons who get less than the standard allowance (10 to 12 mg for adults) of iron in their freely chosen diets Moreover, intakes more liberal than the standard allowance provide a "factor of safety" to cover individual differences in utilization and body needs, as well as to build up stores of iron in the body against possible times of greater need (such as pregnancy, infectious disease, loss of blood in extra menstrual flow, by surgery or hemorrhage).

[18] Sherman, H C, and Lanford, C S, ESSENTIALS OF NUTRITION, p 175, 4th ed, Macmillan, 1957, (based on U S Dept Agric Misc Pub No 691, 1949, and Agricultural Statistics, 1953)

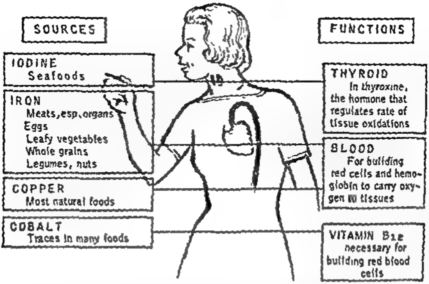


Figure 81 Diagram summarizing chief functions in the body and main food sources of the mineral elements iron, copper, cobalt and iodine.

COPPER

Copper is now regarded as an essential nutrient for humans and for several species of experimental animals. Herbivora (sheep, goats, and cows) are especially susceptible to copper deficiency, and anemias due to copper lack have been observed in such animals grazing on land where the soil is of low copper content. Mention has been made, both under general discussion of mineral elements and in the discussion of nutritional anemia, of the fact that copper plays an essential role in the formation of hemoglobin. Since hemoglobin contains no copper, this element is thought to act to speed up some reaction involved in building hemoglobin, as well as to improve iron absorption. It is also a part of certain body enzymes

Proof that copper is necessary to production of hemoglobin was given by the experiments of Hart, Steenbock, and associates[19] on rats rendered anemic by a diet consisting solely of milk, they found that it was impossible to cure this anemia by giving pure iron salts, but that a cure could be effected by adding to the food the ash of either lettuce or liver It was found that the effective ash contained copper as well as iron, and mixtures of pure iron and copper salts produced rapid relief of anemia and stimulation of growth. These experiments suggested that in some of the anemias in infants on a milk diet, lack of copper might be a limiting factor in addition to lack of iron. In a few cases of nutritional anemia of infancy, the addition of copper to the iron supplement given

[19] Hart, Steenbock, et al, "Copper as a Supplement to Iron for Hemoglobin Building in the Rat," J Biol Chem, 77, 606, 1928.

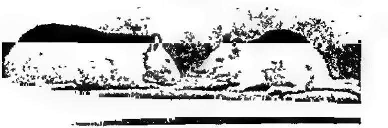


Figure 62 The effect of copper in anemia Rats on same diet, except that the one on the left had very small amounts of copper added to its food (Courtesy of Dr Hart and Dr Steenbock, University of Wisconsin)

does seem to enhance its effectiveness, but most infants respond satisfactorily to administration of iron alone This is doubtless due to the fact that they have a good store of copper in the liver, built up during the fetal stage of development

Lack of copper will almost never be a limiting factor for hemoglobin production in adult human beings The minimum daily requirement is small (estimated at 1 to 2 mg), while the ordinary human diet will provide 2 to 4 mg of this element Copper occurs along with other mineral elements in most natural (unrefined) foods and may be added in processing, as in the pasteurization of milk by passing it over copper rollers, or from cooking in copper utensils As with iron and other metallic elements, stored copper accumulates in the liver, in France, where copper cooking utensils are in common use, there is a saying that "You can tell the age of a Frenchman by the amount of copper in his liver " Cartwright[20] has concluded from studies of body needs and copper content of foods that "an American diet of even mediocre quality easily supplies the daily requirement "

COBALT

Cobalt has been found to be essential for the adequate nutrition of herbivora, such as sheep and cattle These animals, when pastured on soils low in cobalt develop a progressive anemia, muscular atrophy, and extreme emaciation (sometimes called wasting disease) This disorder may be cured by giving either cobalt or vitamin B_{12}, in which cobalt is an essential constituent Cobalt deficiency has not been observed in humans and, among the lower animals, it has been found only in ruminants Apparently such animals utilize cobalt for synthesis of vitamin B_{12} by bacteria in the rumen and develop symptoms due to lack of this element when insufficient amounts are available In other animals and man, microorganisms in the intestine cannot synthesize vitamin B_{12} and it must be supplied, preformed, in the food Since the ordinary diet

[20] Cartwright, G E , "Copper Metabolism in Human Subjects," p 274 in COPPER METABOLISM A SYMPOSIUM ON ANIMAL, PLANT AND SOIL RELATIONSHIPS Johns Hopkins University Press, 1950.

practically always supplies the small amounts of this vitamin that are needed, this explains failure to find cobalt deficiency in man.

It has not been established that cobalt has any other functions in the body except as a necessary component of vitamin B_{12}, although there is some indication that it may be involved in the metabolism of sulfur-containing amino acids. That it is involved, directly or indirectly, in the formation of red blood cells and hemoglobin is made plain by the toxic effects of excessive doses. Undue amounts of cobalt in the diet of man and animal species other than ruminants cause stimulation of bone marrow, with excessive production of red corpuscles (polycythemia) and higher than normal hemoglobin Administration of vitamin C will relieve the toxic effects of too much cobalt. Since traces of cobalt (and of vitamin B_{12}) occur in many foods and only very small amounts are needed, there is no danger of shortage of this element in the human dietary

IODINE

Iodine in the Body

Iodine is one of the elements that are present in minute amounts in the body yet are essential to health Estimates on the amount in the body of a man range from 25 to 50 milligrams, which would be about 1 part iodine to 1½ to 3 million parts of body mass (weight). About three-fifths of all the iodine in the body is concentrated in the thyroid gland, one of the endocrine or ductless glands situated in the lower part of the neck This gland has the ability of selectively absorbing iodine from the blood stream, storing it, and using it in the manufacture of its iodine-containing secretion (hormone) called *thyroxine* The thyroid contains iodine at a level at least 10,000 times that in the blood. Thyroxine is made in the thyroid gland from iodine and one of the amino acids, tyrosine; its molecule contains four atoms of iodine but most of it is bound (for storage) in a complex protein, thyroglobulin. It probably circulates in the blood both in the free state (thyroxine) and some bound with protein (thyroglobulin)

The importance of thyroxine (and thus of iodine) lies in the fact that it speeds up the rate of oxidations, and hence of energy production, in body tissues. Thyroxine was mentioned in the discussion of basal metabolism (p 46) as quantitatively the most important single factor in determining the *rate* of basal metabolism. An insufficiency of thyroxine results in a slow rate of oxidation in body tissues or a low basal metabolism, overproduction of thyroxine, by an overactive thyroid gland, is associated with an abnormally high basal metabolism. Its potency is attested by the fact that the injection into the blood of only 2 milligrams may result in a 20 per cent rise in basal metabolic rate. Obviously, in its medicinal uses, the doses should be carefully controlled by a physician,

as its use in excess may be dangerous. Normally the amount secreted is regulated so that too much of it will not be released at any one time When basal metabolism is maintained at normal, there is a small but fairly constant loss of iodine in the urine, which is the main channel for its excretion

The fact that the thyroid gland possesses such a great ability to selectively absorb iodine has been taken advantage of in two special ways since radioactive iodine has been available Administration of a dose of radioactive iodine is now being used as a test for basal metabolism, in place of the conventional rebreathing of oxygen-rich air to determine amount of oxygen consumption (see page 49) This is an indirect test of basal metabolism, based on the fact that the relative activity of the thyroid is the chief factor in determining the basal metabolic rate and that its relative activity can be gauged by the amount of the radioactive iodine that it takes up The subject receives the radioactive iodine one morning and returns 4 and 24 hours later to sit in front of a Geiger counter to determine how much of the radioactive iodine is in the thyroid tissue If the thyroid is poorly stored with iodine and so is *underactive*, it will pick up and retain more of the radioactive iodine than a normal thyroid would do, if the thyroid is *overactive*, it will presumably be well supplied with iodine and retain much less of the iodine administered

The second use of radioactive iodine is in the treatment of *malignant growths* (cancers) located in the thyroid gland, radioactive iodine, injected into the blood stream, is taken up in relatively large amounts by the thyroid and retained long enough so that its radiations can act locally on the cancerous growth

Occurrence and Prevention of Iodine Deficiency

Simple (or endemic) *goiter* is an enlargement of the thyroid gland due to an insufficient supply of iodine, the gland enlarges in an attempt to compensate thus for the shortage of necessary material for making its hormone, thyroxine This disorder was prevalent for many centuries before its cause was recognized It is mentioned in very early writings, and paintings made in the early and middle ages show many persons with marked enlargement at the throat The classic example is the portrait of the lovely Queen Louise of Prussia, who wears a scarf to hide this disfigurement In some cantons of Switzerland goiter was so common as to be regarded as normal, and possession of an unusually large goiter was considered a mark of distinction Legend has it that burnt sponge was a popular folk remedy for goiter, and the ash of sponge has been found to be fairly rich in iodine Later medical men suggested that painting the goiter with tincture of iodine was helpful But not until Baumann's discovery in 1895 that the thyroid gland contained considerable quantities of iodine was it recognized that there might be a connection between swelling of the gland and its supply of iodine.

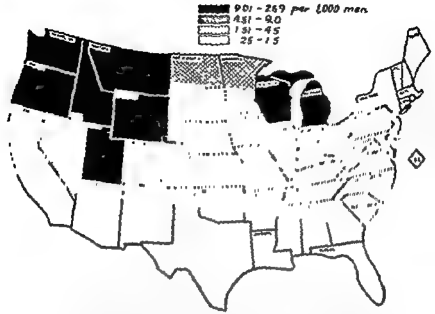


Figure 63. So-called goiter map of the United States, showing (in black) the regions where goiter was *most prevalent*. It also occurred fairly commonly in the cross-barred states, but was *almost totally absent in the states left white*. Since this map was made, the use of preventive measures (iodine in drinking water, iodized salt) has greatly reduced the incidence of simple goiter even in the states where it was most prevalent. (From Geographic Distribution of *Simple Goiter Among* Drafted Men, 1917–18, Love and Davenport, U.S. Dept. of Public Health.)

Meantime it had been commonly known that simple goiter was especially prevalent in certain regions, for the most part these regions were remote from or cut off by mountain ranges from the sea. Outstanding among these districts where goiter was said to be "endemic" were valleys in the mountains of Switzerland, France, and Spain, in the Himalayan Mountains of Asia, on the Andes plateau and in parts of Brazil in South America, and in the basin of the Great Lakes and in the Pacific Northwest in the United States and Canada. When it was suspected that the disease might be due to iodine deficiency, wide surveys were made of the iodine content of the drinking water and soil and of foods grown in this soil, both in goitrous districts and in adjacent districts where this disease was not common. The iodine content of waters varies widely in different regions, being highest near the sea or in areas where iodine-containing rocks are found, the ocean is a great reservoir of iodine salts and sea-spray is carried inland for considerable distances to enrich the soils in this element, so that vegetation grown in districts nearer the sea is richer in iodine than that grown in iodine-poor soils in more remote areas. Hence, the people who lived in the areas where goiter was endemic were found to be getting less than normal amounts of iodine in water and in foods produced in their localities. Also it was

found that men were less subject to simple goiter than were women, and that the thyroid trouble was most likely to make its appearance at such periods as adolescence and during pregnancy, when the need for mineral elements is increased. Babies might be born with goitrous necks and be too weak to survive long, even though the mother had not shown signs of iodine deficiency.

In goitrous regions, farm animals showed the same evidences of iodine deficiency as humans, and their tendency to produce still-born or weak and sickly young was a source of financial loss and concern to farmers Hart and Steenbock[21] at the University of Wisconsin in 1918 published results of a study on the "hairless pig malady," a condition in which apparently normal sows give birth to still-born young that are nearly hairless and have thick, goitrous necks They found that this was the result of iodine deficiency in the mother and that the addition of 10 grams of iodide per 100 pounds of feed permitted the sows to produce normal young.

This report, and other evidence, stimulated Marine and Kimball[22] to see whether beneficial results might follow administration of small amounts of iodide to school children in Akron, Ohio, where mild goiter was common among adolescent children In an experiment that lasted 2½ years, small doses of iodide were administered in drinking

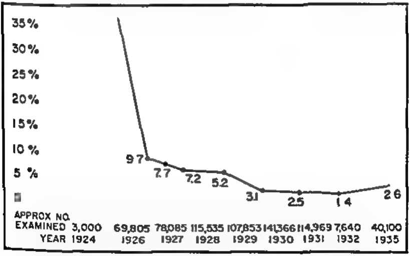


Figure [illegible] Graph showing the marked decrease in simple goiter among Detroit school children between 1924 and 1935, due to the use of iodized salt. (From Kimball, O P, Journal of American Medical Association, 1937)

[21] [illegible] plasia and the Relation of Iodine [illegible] 1918

[illegible] f Simple Goiter in Man," Arch.

Figure 65 A group of women from a goitrous region in Guatemala, showing the prevalence of simple goiter in many isolated sections of the world today (Courtesy of Dr N S Scrimshaw, Director of the Institute of Nutrition of Central America and Panama)

water (twice weekly for a month, repeated twice yearly) to over 2,000 volunteers, while an equal number of children who received no treatment served as controls. Examination of thyroid glands before and during the tests, showed that 99 per cent of the goiter development that might have been expected (i e, the extent to which it developed in the control group) was prevented and about 58 per cent of the enlarged thyroids already present showed decrease in size as a result of the administration of sodium iodide to the experimental group. Similar treatment with iodides, undertaken among the school children in three cantons of Switzerland, produced a tremendous decrease in the incidence of goiter. This work established without question the practicability of prevention of simple goiter in districts where it is common by suitable administration of small quantities of some iodine compound. In some localities, soluble iodine salts were added to city water supplies at certain seasons in amounts under direction of public health officers, but this did not help country people, preventives given to children in schools failed to reach preschool children and pregnant women, a group especially in need of extra iodine. Iodized salt (refined salt to which sodium or potassium iodide had been added in amounts up to 0.01 per cent) [illegible]s the [illegible]-cost [illegible] nt in crude salt but removed in the refining process It is now recommended for use in all localities where simple goiter is endemic.[21] In Switzerland

[21] Kimball, O P, "Iodized Salt for Prophylaxis of Endemic Goiter," J A M A, 130, 80, 1946, and Editorial, "Iodine and Table Salt," ibid, 135, 434, 1947.

and Canada iodization of all table salt is required by law, but in most parts of the United States educating people to its use is a public health problem

Michigan, where simple goiter was common, was one of the first states to launch such a preventive campaign Physicians and public health officials united in publicizing iodized salt as a goiter preventive and urging its universal use in the state Over a period of years (1924–1935), the incidence of endemic goiter was markedly decreased—in Detroit from 35 per cent in 1924 to only 2 [illegible] per cent in 1935 [24] A similar campaign was carried out in Switzerland, where by 1929 iodized salt was used exclusively in nine cantons and freely in most of the others Five years after its use was made compulsory in the canton of Appenzall, simple goiter among young school children had disappeared and there were only one-fourth as many operations for relief of goiter among adults

Although the cause and means of prevention of endemic goiter have been understood for nearly forty years and much progress towards its eradication has been made in certain countries, it is perhaps surprising to find that it was recently stated by the Nutrition Section of the World Health Organization (U N) to be one of the most prevalent nutritional deficiency diseases in the world Much remains to be done in clearing up the last of it even in more advanced countries, while it is still rife in many backward countries and out-of-the-way places, such as isolated valleys of Austria, northern India, South and Central America, and Jugoslavia [25] There is plenty of work yet to be done by educational, medical, and public health agencies before its final eradication is accomplished

Iodine Requirement and Content of Foods

It is evident that iodine is present in the body and in foods in amounts almost small enough to be counted as "traces," and naturally the daily requirement for this element will be very small Because of the minute amounts involved, it is difficult to determine with any degree of accuracy either the quantities of iodine in foods or the iodine balance in the body The National Research Council estimates the iodine requirement as probably about 2–4 micrograms (thousandths of a milligram) per day for each kilogram of body weight, for a 70 kg adult this would mean about 0 15 to 0 30 milligrams daily This amount should be easily obtainable in food and drink in nongoitrous regions Quantities which are taken in excess of the minimum requirement serve to build up

a reserve store in the thyroid gland, available for use at times when the requirement is increased (puberty, pregnancy, menopause, some infections, exposure to cold, and excess of some other nutrients such as calcium) As with other mineral elements, doubtless the quantity required differs somewhat with different individuals. Possibly the smallness of the quantities of iodine required may best be appreciated by the statement that the standard allowance of iron for an adult for a week would weigh about the same as a whole year's supply of iodine.

The problem of the iodine content of foods is complicated by the facts that the amounts present are so minute and also *vary greatly* in different regions Although we usually state the amounts of other nutrients in foods in terms of parts per hundred parts of food (grams of carbohydrate, fat, or protein per 100 grams of food, and milligrams of the other mineral elements per 100 gm food), the iodine content of foods is stated in terms of parts *per billion*. Sea foods are among the richest food sources of iodine, as shown by the few examples given below:

	Iodine, Parts per billion of fresh material
Salmon (canned or fresh)	300–700
Oysters, avg	492
Haddock, avg	3,130
Cod liver oil	3,000–13,000

The amount of this element in milk and eggs is dependent upon that present in the feed of the producing animal, milk with high iodine content has been produced by mixing iodides in the cows' feed Among vegetable foods, the iodine content is highest in leaves and tubers or roots, lowest in seeds such as the cereal grains. Foods grown on iodine-poor soil (in goiter regions) always contain much less iodine than do those grown where the soil has a higher content of iodine salts (nongoitrous regions), differences which may vary from 100 to over 1,000 per cent In general, analyses indicate that milk, butter, and vegetables, produced in regions where soil is at least of moderate iodine content, are fairly good sources of iodine, grains, legumes, and fresh fruit (even from nongoitrous areas) are of lower iodine content, salt-water fish, shellfish, and cod liver oil are relatively rich in iodine.

Persons living in nongoitrous areas will be practically certain to get enough iodine to meet their requirement on any well balanced diet (one not too high in cereals and highly refined foods), plus that in drinking water, which alone may satisfy the requirement in some areas Those living in goitrous regions may supplement their diet with sea foods and with canned vegetables grown in and imported from regions where there is more iodine in the soil (near the sea) However, by using iodized salt in such areas, people may be assured of getting their quota of this element without considering the small and variable amounts in foods.

QUESTIONS AND PROBLEMS

1 In what special tissue is most of the iron in the body found, and in what special substance in this tissue? What function does it fulfill in this tissue, and what chemical property enables it to carry out this function? How do the smaller amounts of iron located in tissue cells help in oxidation-reduction processes vital to life of cells?

2 What are the minimum requirement and standard allowance for iron daily for a grown man, a woman? At what periods of life is the need for this element increased, and why? Why is iron sometimes referred to as "the one way element"? Explain how iron is conserved by the body and how a liberal supply of it in the diet can build up reserve stores that serve to protect the body in times of extra need.

3 Distinguish between the three general types of anemia and give the causative factor in each What are the symptoms of nutritional anemia and under what conditions may it be caused? Does the existence of nutritional anemia necessarily mean that the diet furnished too little iron? Explain reasons for your answer What kind of diet will help to prevent or cure nutritional anemia? What other nutritional factors besides iron are important in such a diet and why?

4 Can the body utilize either inorganic or organic iron equally well? In what form or forms is iron most readily absorbed from the intestine? Mention three factors that favor and three that are unfavorable for iron absorption Why is a greater proportion of the iron ingested absorbed and utilized when the need of the body for this element is increased?

5 Is copper an essential element? For what special purpose is it necessary? Why does a rat become anemic if kept for long on a diet consisting only of milk? Why can such an anemia not be cured by giving either iron alone or copper alone? If a baby developed nutritional anemia, would it be of assistance in curing the anemia to give some copper along with some form of iron? Explain why most people are sure of getting enough copper in their food to meet their requirement for this element

6 Is cobalt essential for humans? For what animals is it essential? What are the symptoms of cobalt deficiency and how may it be caused? In what vitamin is cobalt found and why is anemia a prominent symptom in cobalt deficiency in ruminants like sheep or cattle?

7 Why is iodine essential in small amounts for body welfare? In what tissue is this element concentrated and what is its function there? Can iodine be stored in the body and, if so, where? What is a ductless gland, a hormone, the name of the iodine-containing hormone of the thyroid gland, the influence of this hormone on body metabolism (tissue oxidations)?

8 Simple goiter is a deficiency disease caused by lack of what element? In what regions is it most prevalent, and why? At what periods

of life is it most likely to develop, and why? Describe two public health measures that have been used successfully in preventing simple goiter.

9 Name five foods that are relatively rich in iron, three that are relatively rich in iodine. What kinds of food are poor in iron, in iodine?

10 Record all the foods you ate on a typical day, with quantities of each, and calculate the amount of iron furnished by this day's diet Use either Table 10 for iron content of foods (p 171) or tables in the Appendix for nutritive values of foods in average servings. Does the amount of iron in this day's diet come up to the standard allowance? If not, what changes could be made to furnish more iron?

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of life is it most likely to develop, and why? Describe two public health measures that have been used successfully in preventing simple goiter.

9. Name five foods that are relatively rich in iron, three that are relatively rich in iodine. What kinds of food are poor in iron, in iodine?

10. Record all the foods you ate on a typical day, with quantities of each, and calculate the amount of iron furnished by this day's diet. Use either Table 10 for iron content of foods (p. 171) or tables in the Appendix for nutritive values of foods in average servings. Does the amount of iron in this day's diet come up to the standard allowance? If not, what changes could be made to furnish more iron?

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General Information About Vitamins

Discovery

The most dramatic chapter of nutrition deals with the discovery and study of the group of ***body regulators*** called ***vitamins***. Up to the early part of the twentieth century, it was generally considered that only fuel foodstuffs, protein, and mineral elements were needed for normal nutrition, in which event the proper amounts of purified proteins, carbohydrates, fats, and mineral salts should suffice to supply all needs of the body. Most investigators had paid little attention to the experiments of Lunin in the 1880's, when he found, disconcertingly, that mice died if fed on an artificial mixture of all the then known constituents of milk. Lunin concluded, "A natural food, such as milk, must therefore contain besides these known principal ingredients small quantities of unknown substances essential to life."

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CHAPTER TEN

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and carbohydrates, to which all the presumably necessary mineral matter had been added. Less than one third of a teaspoonful of milk, added to the highly purified diet, made all the difference between life and death for the experimental animals. An alcoholic extract of dried milk or of certain vegetables also enabled the animals on purified diets to live and grow, but the *ash* of milk or vegetables was ineffectual Thus Hopkins showed that the essential "unknowns" that exist in foods in the natural state are *organic* (rather than inorganic) substances that can be dissolved in alcohol For his work in establishing the existence of the substances we now call vitamins, Hopkins later received a Nobel prize award.

Meantime (1908–1911) Osborne and Mendel in America were pursuing the same kind of animal experimentation with diets composed of chemically pure foodstuffs which fulfilled all the hitherto recognized requirements for good nutrition. Their rats could be kept alive and growing by inclusion in the diet of small amounts of "protein-free milk," a powder made by removing both fat and protein from milk and evaporating the resulting whey Again the ash of the whey showed no protecting powers. These investigators, and McCollum and Davis of Wisconsin, showed independently (1913) that fatty foods, such as butter and egg yolk, contain traces of another type of substances also required for normal nutrition So it was proved that not only are these nutritive essentials organic in nature but some of them are soluble in water while others are insoluble in water but are soluble in fats and fat solvents. It became evident that there must be two or more of these mysterious but potent substances carried by natural foods

These essential "trace" nutrients were called by some *"food hormones"* McCollum proposed the terms "fat-soluble A" and "water-soluble B" to designate the *"accessory food substances"* found in butter-fat and milk whey, respectively. In 1912 Funk, having obtained from rice bran a concentrated preparation of one of these potent substances that seemed to belong to the class of chemical compounds called amines, proposed that collectively they should be known as *"vitamines"* (amines essential to life). This name caught the popular fancy and has persisted, despite the fact that the one which suggested the name to Funk turned out to be one of the very few that were amines At the suggestion of chemists, the final *e* was dropped in order to avoid any chemical significance.

Definition

Vitamins may be defined as organic compounds, different from any of the previously described food materials, which are needed only in small amounts but are *necessary for normal growth and the maintenance of health.* All living organisms need vitamins, but not every vitamin that has been discovered is needed by all animals Plants (including yeasts

and bacteria) can manufacture most of the vitamins that they require, but animals must have most of their vitamins supplied in food There are differences between the vitamin requirements of human beings and of the lower animals

The action of vitamins is not unlike that of "trace" minerals such as iodine and copper, in that the presence or absence of very small amounts of them in the food means the difference between normal and abnormal functioning of the body The potent effects of very small quantities in regulating body processes also remind us somewhat of the action of the hormones (thyroxine, adrenaline, etc) that are formed by various ductless glands Vitamins differ from the mineral elements in that they are *organic* substances (some of them complex compounds), while they differ from hormones in that (at least for the most part) they are not formed within the body but *must be supplied in food*

It is easier to describe the effects of vitamins or of the lack of them in the food, than to define them as a group This is because they have turned out to be a heterogeneous group of substances which differ widely in their chemical nature and in their physiological action Also a few vitamins, required to be furnished in the food of man, can be formed by some animals in their own bodies Thus men get scurvy on diets that provide no vitamin C in fresh fruit or vegetables, but rats make this vitamin in their bodies and do not need it in food

Distribution in Foods

The existence of vitamins was overlooked for many years because the foods consumed by man usually provided enough of them to prevent disastrous results to health Most foods, as supplied by nature, contain some of several vitamins, and the foods in an ordinary mixed diet supplement each other in vitamin content The quantities of these substances present in foods were too small to have been detected by chemists, and fortunately only small amounts of them are required to avert nutritional disaster In occasional instances, when the choice of foods was limited for one reason or another, diseased conditions did arise (e g , scurvy occurred on long sea voyages, in besieged cities, or in times of famine), but it was many years before it dawned upon people that such mysterious diseases might be caused by the *lack* of something in the diet Since refined foods, such as highly milled grains, have assumed a more prominent place in the diet, ill health due to vitamin deficiencies has become more frequent

What foods are our chief sources of vitamins? Animals get most of their vitamins either directly from plants, in which they are formed by the action of sunlight, or indirectly from animals which have fed on plants The green leaves of the plant are its chemical laboratories in which vitamins are made along with many other substances. Hence, green leafy vegetables have high content of most vitamins, as have also

and carbohydrates, to which all the presumably necessary mineral matter had been added. Less than one third of a teaspoonful of milk, added to the highly purified diet, made all the difference between life and death for the experimental animals. An alcoholic extract of dried milk or of certain vegetables also enabled the animals on purified diets to live and grow, but the *ash* of milk or vegetables was ineffectual. Thus Hopkins *showed that the essential "unknowns" that exist in foods in the natural* state are *organic* (rather than inorganic) substances that can be dissolved in alcohol. For his work in establishing the existence of the substances we now call vitamins, Hopkins later received a Nobel prize award

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mins have not been proved to be essential for man Those that have been shown to be essential in human food in fairly considerable amounts will be taken up individually in the three following chapters

The naming of vitamins at first presented a problem, since little was known as to their chemistry. In fact, an early suggestion was that the two groups (water-soluble and fat-soluble) should be called "factor X" and "factor Y." As the groups became separated into several factors, the different vitamins were designated by the *letters* of the alphabet, determined either by the order of their discovery or by the initial letter of some word suggestive of their role in nutrition, e g, vitamin K from the Danish word for coagulation (of blood) The fraction originally known as vitamin B became subdivided into many different chemical substances, which were called B_1, B_2, etc, or by their chemical names As the chemical identity of the different vitamins was established, *chemical names* gradually supplanted the earlier designation by letters and, of course, they are to be preferred as more definite and descriptive than letter symbols, at least from the chemist's viewpoint However, the letter system is still in common use and offers a convenient "shorthand" way of referring to individual vitamins In the following chapters, we shall use both letters and chemical names, usually stated together, in order to familiarize the student gradually with the chemical nomenclature of the vitamins

Isolation and Synthesis of Vitamins

These technical terms are used to describe the long and difficult labors of the chemists, which were necessary in order to find out what the vitamin "unknowns" consisted of chemically and how to make them in the laboratory At first this seemed an impossible task, since vitamins were present in foods in such minute traces The dry weight of a man's food intake for a day is from one to one and a half pounds, whereas the total vitamins in his food, if separated, would appear as only a few crystals—about one part per five thousand parts of dry food and of course much less in the moist foods as eaten

To add to the difficulty, vitamins are organic substances and hence liable to destruction by heat, oxidation, and chemical processes used in their extraction But the magnitude of the task and the interesting role of vitamins in nutrition constituted a challenge to chemists, who continued their painstaking labors sometimes for twenty-five or thirty years before the goal was attained. Scientists in all parts of the world participated in the effort to transform vitamins from unknown mysterious substances, found only in traces in foods, into known, *pure chemical compounds* that could be made at will

The first step was to obtain concentrated preparations of vitamins from materials where they occurred in nature in largest amounts. Vitamins A and D were extracted from fish liver oils, and vitamins B_1 and B_2

the green, growing shoots of plants, seeds, such as legumes, nuts, and whole grain cereals, also have a good content of certain vitamins, root vegetables and fruits and vegetables of high water content usually contain smaller amounts of most vitamins, although there are notable exceptions in the case of certain vitamins or of special fruits and vegetables. It should be remembered that the different vitamins are often unevenly distributed in foods, while the vitamin content of fruits and vegetables may vary considerably, depending on the soil on which they are grown, their stage of *ripeness* when picked, conditions of storage, and other factors.

The lean flesh of animals (muscle meats) provide certain vitamins, but organs, such as liver and kidneys, are much richer in vitamin content Certain animals are useful to man in that they concentrate vitamins in foods suitable for human consumption. Thus cows and hens put vitamins from their food into *milk* and the *yolks of eggs* which are valuable sources of vitamins. The vitamin content of eggs and milk will vary according to the relative amount of vitamins in the animals' feed (e.g, cows on green pasturage in summer give milk of higher vitamin content than do those fed only dried hay and grain in winter). Fish store certain vitamins in their body fat and especially in their livers, which accounts for the fact that *fish liver oils* are the richest source of these particular vitamins

Naturally, the fat-soluble vitamins are found chiefly in fatty foods —liver, butter, egg yolk, etc Water-soluble vitamins are more abundant in fruits and vegetables, whole grains and legumes, and lean meats Milk carries both water-soluble and fat-soluble vitamins, the latter in the fat globules. Although such facts about the general distribution of vitamins in foods are interesting and useful, there are many exceptions in regard to individual vitamins, so that each vitamin must be studied separately to determine what foods are needed to furnish it in amounts adequate for health.

Number and Naming of Vitamins

Attracted by the mysterious but potent role of these newly discovered substances, nutritionists continued to investigate vitamins with unflagging zeal. It soon became apparent that "fat-soluble A" and "water-soluble B" both comprised not one but a *group* of vitamins, each of which had a separate, indispensable role in nutrition and different properties Almost the only property which the members of each group had in common was their solubility, either in water or in fats and fat solvents The water-soluble group proved especially complex, and years of patient research have probably not yet revealed all of its factors At least thirteen different vitamins have thus far been recognized and their chemical identity established, while perhaps as many more have been said to exist and to be necessary for health of certain animals. A number of the recognized vita-

eral elements, as well as hormones. Such research, although difficult and slow, offers the same challenge to the biochemists which determination of the chemical nature of the vitamins offered in former years

Measurement

When vitamins were made available as pure substances, a great impetus was given to their more exact measurement In earlier years the quantity of a given vitamin in foods was assayed approximately in "*biological units*," the amount required to produce a certain nutritional response in some animal—either to give a standard rate of growth, or to protect from or cure the deficiency disease caused by lack of that vitamin But animals of the same species, even from the same laboratory stock and under standardized conditions, varied somewhat in their biological response to vitamins, so that such units were at best an approximate measure

As the various vitamins became known as pure substances, so-called "*International units*" were established, based on a definite weight of the actual substance—e g , one International unit of vitamin C is 0 05 milligram of pure ascorbic acid Although animals are still used to assay vitamins in foods or drugs, more accurate results are obtained because they are always compared with the effect of known quantities of the pure substance on control animals. Amounts of vitamins A and D in foods, and in pharmaceutical vitamin preparations, are usually stated in terms of International units

The equivalent of a unit of each of these vitamins in terms of the pure vitamin (or provitamin) is as follows

1 International unit of vitamin A = 0 0006 mg β carotene
1 " " " " D = 0 000025 mg calciferol

With other vitamins, however, the quantity required and amounts present in foods can be stated directly in terms of *weight* units, milligrams or micrograms (1/1000 or 1/1,000,000 of a gram, respectively) or gammas, expressed as γ, and this method of expressing their measure is preferred as the most accurate In order to avoid decimals, usually the weight is given as milligrams or micrograms, thus 0 0004 gm. would be 0 4 mg or 400 γ gammas or micrograms

Minimum Requirements and Optimum Allowances

Although the fact that we measure vitamins in such small units as milligrams or micrograms makes it apparent that they exist in foods in "trace" quantities, still the total amounts of them needed by the body are somewhat comparable to the amounts of certain minerals required By actual weight, the ***minimum daily requirements*** of normal adults for the different vitamins range from less than 01 milligram of vitamin D to at least 10 milligrams of vitamin C A man probably needs less vitamin D than iodine (or other "trace minerals") per day, but his intake of niacin

from rice polishings, wheat germ, and dried yeasts; vitamin C was first obtained in concentrated form from citrus fruits and red peppers. These crude extracts were further concentrated and purified until small quantities of apparently pure substances (usually crystals) were obtained, which were tested for vitamin activity and analyzed chemically. The final steps in determining the chemical groupings in the molecule of the pure substance, and finding out how to put these groups together to make the substance in the laboratory, were probably the most difficult part of the task.

Most of the longest-known vitamins (those needed by man in sizable amounts) are now obtainable, either in *concentrated preparations* or as *pure, synthetic substances*, at drugstores for a moderate cost.

The following thirteen vitamins have been isolated as chemical compounds, the composition and structure of which are known, and most of them can be made in the laboratory:

Vitamin	*Chemical name*	
Vitamin A	Axerophthol	
Vitamin B_1	Thiamine	B-complex
Vitamin B_2	Riboflavin	B-complex
Vitamin B_6	Pyridoxine	B-complex
Niacin	Nicotinic acid (or its amide)	B-complex
	Pantothenic acid	B-complex
	Biotin	B-complex
Folic acid	Pteroylglutamic acid	B-complex
Vitamin B_{12}	Cobalamin	B-complex
Vitamin C	Ascorbic acid	
Vitamins D	Calciferol and 7-dehydrocholesterol	
Vitamins E	Tocopherols	
Vitamins K	Phylloquinones	

In order to summarize for the student the general progress of vitamin research and to avoid tiresome repetition of dates of historic discoveries in the following chapters, we may divide the development of this knowledge roughly into three periods

Discovery of vitamins and of fat-soluble and water-soluble fractions, 1906 to 1913

Discovery of individual vitamins in these two fractions, 1926 to 1938

Isolation and synthesis of the individual vitamins, 1932 to 1945

Doubtless there remain other vitamins yet to be discovered, this was exemplified by the discovery in 1948 of vitamin B_{12}, a previously suspected nutritional factor but one that had been difficult to isolate However, it is apparent that, in over 50 years of research, most of the groundwork has been done in establishing the existence of individual vitamins, their chemical nature, and their occurrence in foods. Research is now centered on following vitamins *within the body* in determining (1) *how* they bring about their characteristic effects on body tissues, and (2) possible ***interrelations*** between different vitamins and between vitamins and other nutrient substances, such as proteins, carbohydrates, and min-

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	Pantothenic acid	B-complex
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Folic acid	Pteroylglutamic acid	B-complex
Vitamin B_{12}	Cobalamin	B-complex
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may result from lack of any *one* of several vitamins that are needed for the welfare of these organs or tissues

It should also be remembered that stunting of growth, lack of appetite, poor utilization of food, etc, may be caused by an insufficiency of nutritive essentials other than vitamins Lack of enough foodstuffs (energy), of some one essential amino acid or mineral element may cause growth to be slowed or cease, lack of calcium or phosphorus may result in poor growth or quality of bones, insufficient iron may be the main factor in producing some anemias, while lack of necessary vitamins (folic acid or B_{12}) may be the causative factor in others So some of the more general symptoms of vitamin lack are not specific, i e, not limited to vitamins

Mode of Action of Vitamins

As Catalysts in the Tissues *How* do vitamins bring about their effects, and *why* are small amounts of them so indispensable for life? Formerly the "life or death" importance of the presence or lack of these substances in "trace" amounts seemed mysterious, but recent research has given us at least a part of the answer to this enigma, namely, most if not all vitamins act as catalysts A catalyst is a substance that speeds up a chemical reaction without itself taking part in it, much as a jolly person may promote the "life" of a party merely by his presence Most of the hundreds of chemical reactions taking place in plant and animal tis-

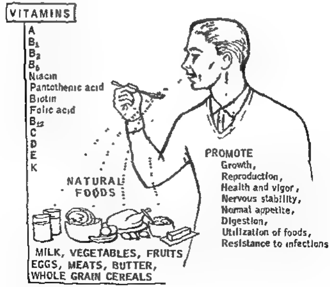

Figure 66 Different vitamins found in natural foods and their general functions in the body

(one of the B-complex vitamins) should be of approximately the same magnitude as his iron intake, while the recommended allowance of vitamin C for adults (70–75 mg) is about seven times the iron allowance As with the mineral elements, there is increased need for vitamins during the growth period and in pregnancy.

The *standard allowances* for vitamins are usually several times the quantities that are necessary to prevent symptoms of a deficiency disease This is because it has been shown that additional amounts, above those which will just prevent disease, bring returns in better growth of young animals or children and in increased vitality of adults. Usually from two to four times the minimum requirement will be found to be the *optimum* amount for positive health

The recommended allowances of the Food and Nutrition Board, National Research Council, for different vitamins all allow a very liberal amount over and above *minimum* requirement, in the effort to raise general health standards However, when these optimum allowances are used as a "yardstick" for measuring the adequacy of diets, it should be remembered that usually far less than the recommended quantity will suffice to prevent symptoms of deficiency disease For instance, 25 mg (or less) of vitamin C (ascorbic acid) daily is enough to prevent scurvy, but 70–75 mg. are recommended for normal adults The Board definitely states that it has set rather high standards as something to aim at, with the desire of raising the general nutritional level of the country

General Uses of Vitamins in the Body

Although individual vitamins have special functions, which will be taken up in the following chapters, as a group of body regulators they share in certain functions, such as

(1) the promotion of growth,
(2) the promotion of ability to produce healthy offspring,
(3) the maintenance of health and vigor through promoting
 (a) normal functioning of the digestive tract,
 (b) normal nutrition, especially utilization of mineral elements and oxidation of carbohydrates,
 (c) nervous stability,
 (d) health of tissues and resistance to bacterial infections.

It is worth while to keep in mind the above *general uses* of vitamins, since they recur constantly in the study of the functions of individual vitamins. Also, it should be emphasized that, when several vitamins participate in promoting some function of the body, lack of any *one* of them will suffice to inhibit this function For example, vitamins A, B_1, B_2, C, and D all have a direct influence in stimulating growth When any one of these vitamins is supplied in inadequate amounts, growth will be stunted, even though the food contains plenty of the other vitamins needed for growth. In similar manner, damage to reproductive ability, to functioning of the digestive tract, and to the health of various tissues

To safeguard both the vitamin and mineral content of the diet, the following *dietary pattern* has been suggested by the Food and Nutrition Board of the National Research Council

- *Milk*—2 or more glasses daily for adults, 3 to 4 glasses daily for children
- *Vegetables*—2 or more servings daily besides potato, raw, green, and yellow vegetables should be served frequently
- *Fruits*—2 or more servings daily, one of which should be citrus fruit or tomato
- *Eggs*—3 to [illegible] week
- *Meat, Cheese, Fish, or Legumes*—1 or more servings daily
- *Cereal or Bread*—Most of it whole grain or "enriched"
- *Butter or Fortified Margarine*—2 or more tablespoons daily

Other foods will be needed to supply calories for growth and activity but, if a person gets the above-mentioned foods each day, there will be little danger of vitamin shortage The foods which are chiefly responsible for supplying different individual vitamins will be made clear in the following chapters

QUESTIONS

1 If vitamins are a group of unrelated organic compounds that are needed in small amounts for normal functioning of body tissues but cannot be made within the body, why are the essential amino acids and essential fatty acids not classed as vitamins? Why are the "trace" minerals, which are needed in very small amounts and must be supplied in food for normal body functioning, not included with the vitamins? Why are hormones, such as adrenaline and thyroxine, not called vitamins?

2 The rat and dog do not have to have ascorbic acid (vitamin C) supplied in their food, because they can make it in their own body tissues, men, monkeys, and guinea pigs cannot make this substance within their bodies, and hence must get it from foods Could you say that ascorbic acid is a hormone for rats and a vitamin for man?

3 When was it first known that animals could not be maintained in health, or even survive, on diets of purified foodstuffs that provided plenty of calories, protein, and all necessary mineral elements? Approximately how long before it was recognized that natural foods provided traces of definite *organic substances* that were absent from the purified foodstuffs? When were these substances first called "vitamines"? Who first distinguished between two groups of these substances and called them "fat-soluble A" and "water-soluble B"?

4 What is meant by the following terms that are used in connection with vitamins biological assay, biological units, international units, U S Pharmacopeia units, vitamin concentrates, synthetic vitamins, a milligram, a microgram, minimum requirement, standard allowance?

sues, which are essential to the life of the organisms, require catalysts to cause them to occur; the special type of catalysts that promote these reactions in living tissues are known as *enzymes.*

Many of the vitamins have been found to occur in the body as part of enzymes that are responsible for promoting some essential chemical reaction. For instance, animal cells get most of the energy required for their life processes through oxidation of the carbohydrate, glucose, which takes place in many intermediate steps so that energy is set free very gradually instead of all at once. Several of the B-complex vitamins have been shown to be a part of enzymes and coenzymes (substances that aid enzymes in their tasks), each of which catalyzes only one special step in the oxidation of carbohydrate. The absence of any one of these enzymes means a failure of some indispensable link in the chain of tissue oxidations, hence the lack of a vitamin that is an essential part of such an enzyme can cripple vital oxidation processes in cells so that tissues all over the body may suffer. Since enzymes, as catalysts, are not used up in the reactions they promote, naturally only small amounts of them are needed.

Other vitamins are known to occur in enzymes concerned with protein or mineral metabolism (as will be described in connection with individual vitamins in the following chapters). Although it has not yet been established that all vitamins play their role through enzyme action, it seems probable that they act in some manner to promote chemical reactions that are essential for healthy tissues.

Main Objective of Knowledge of Vitamins

The chief aim of the study of vitamins is to see that human beings get plenty of *all* of the various vitamins needed to promote positive health. This should not be lost sight of in the maze of interesting scientific facts which research on vitamins has brought to light. The need for vitamins begins before birth, since it is important that the diet of a pregnant woman should be rich in vitamins if the infant is to start life with a liberal store of these substances in its body. Children must be liberally supplied with numerous vitamins in order to build health tissues and make the best growth. In adult life, a plentiful supply of all needed vitamins may mean better health and longer life. Although vitamin concentrates and pure, synthetic vitamins are very useful for the cure of the sick, the objective of nutrition is to have enough of all the needed vitamins *in the diet* for *prevention* of disease and promotion of health.

How to Get Plenty of Vitamins in the Diet

The most practical *general rule* for increasing the vitamin content of the diet is to take larger amounts of whole milk, whole grains, fruits, and vegetables, along with some butter, eggs, and meats (especially organ meats).

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5 Why were the vitamins designated by letters of the alphabet? In general, is it better to call a vitamin by its chemical name, when it has been given one, or by a letter, and why? Are letters more convenient in some cases, for instance vitamin A instead of axerophthol, vitamin E instead of α-, β-, and γ-tocopherol? Why do we still speak of the group of *vitamins D instead of calling them by chemical names? Can you give* the chemical names for vitamins B_1, B_2, B_6, and C?

6. How can the vitamin content of foods be measured? From the directions on page 197, as to how to get plenty of vitamins in the diet, what foods or classes of foods would you say are relatively rich in one or more vitamins? In what types of food are fat-soluble vitamins found? What classes of food are good purveyors of water-soluble vitamins? Name three foods that furnish considerable amounts of some water-soluble and fat-soluble vitamins together Name five foods that carry little or no vitamins.

7. Give the general uses of vitamins in the body, i.e, functions in *which several vitamins participate and to which all of them are essential.* Would rats grow on a diet which furnished adequate energy, proteins, minerals, and all of the vitamins except vitamin A? Why? If it is true that vitamins A and C help to prevent infections, would you expect to raise bacterial resistance satisfactorily by taking a diet rich in one of these vitamins and poor in the other?

8 Explain how some vitamins have been shown to bring about their effects in the body by acting as catalysts Why may lack of a vitamin, which forms part of an enzyme responsible for bringing about some reaction vital to metabolism of tissue cells, result in widespread tissue damage?

9. Why is it important that the vitamin intake should be well balanced, i e., include all of the essential vitamins in the approximate proportions in which they are required by the body? Why is it advantageous to get vitamins in natural foods instead of eating a vitamin-poor diet and taking synthetic vitamins in pills or capsules?

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eventually to isolation of the lacking substance as a vitamin How far back in history the disease occurred is not certain, but from records of the Crusaders it is evident that they suffered from scurvy. In the 15th and 16th centuries, it was a scourge throughout Europe, so much so that medical men wondered if all disease might not be outgrowths of scurvy It was particularly prevalent and severe on long voyages of sailing ships, in beseiged cities, and in times of crop failures—in short, wherever fresh foods were unavailable When Vasco de Gama made his long voyage around the Cape of Good Hope, nearly two thirds of his crew perished from scurvy, the lives of many of the men with the explorer Cartier, when obliged to spend the winter of 1535 in Canada, were saved because they learned from the Indians that a "brew" made from the growing tips of the spruce and other trees was a cure for this malady, by the time of the historic voyage of Captain Cook, he knew enough about the prevention of this disease to stock the ship with fresh vegetables and fruits at every port at which it put in, thereby keeping himself and crew well throughout the long trip In 1757, Lind published the report of experiments made on ships of the British Navy, which proved that lemons would prevent or cure the disease, but not until 1795 was "lime juice" made a regulation issue of diet on such ships, after which British sailors became known as "limeys" The explorers of the New World brought the potato to Europe and, as potatoes became a food staple there, scurvy disappeared, epidemics of it reappeared after disastrous failures of the potato crop in certain regions, as in Norway and in Ireland on several occasions Thus it became generally recognized that citrus fruits and fresh vegetables were preventives against scurvy, but nearly 150 years were

Figure 67 A typical case of adult scurvy, showing the numerous petechiae—spots where blood has effused to the skin (L J Harris, Vitamins in Theory and Practice, Macmillan Co)

Ascorbic Acid (Vitamin C)

Ascorbic acid *makes a good starting point for the study of individual* vitamins, since (1) it was the first vitamin to be identified chemically, (2) it is the simplest of the substances now known to function as vitamins, (3) it is the most unstable of the vitamins, yet it is the one needed in largest amounts by man, and (4) the deficiency disease caused by lack of it has been known for centuries. As vitamins A and B (B_1) had been

designated as *vitamin C*. After its chemical structure was [illegible] became known as *ascorbic acid*, and the two terms may be used interchangeably.

Effects of Lack of Vitamin C

The Saga of Scurvy. Serious cases of scurvy, a disease due to prolonged lack of vitamin C, are seldom seen now but the story of its incidence and conquest are of great interest because they led to discovery that a disease could be caused by lack of some intangible in the diet, and

as Labrador and Newfoundland) where fresh, raw foods are difficult to obtain, and when infection develops in persons who habitually take a diet low in vitamin C. Thus, as with minerals, a deficiency shows up in persons whose intake is on the border line of sufficiency, when there is greater need of the vitamin (as in growth), or under conditions of physiological stress.

In young children, symptoms of latent scurvy are *failure to grow* properly, restlessness and irritability, and sometimes swollen and painful joints. Signs of vitamin C deficiency in older children and adults are usually listlessness, lack of endurance, fleeting pains in the legs and joints (often mistaken for rheumatism), small hemorrhages under the skin, or spongy gums which bleed easily.

Even less clearly defined symptoms have been associated by various authorities with the habitual intake of less than optimal amounts of vitamin C. Plimmer pointed out that general poor health often existed in persons whose vitamin C intake was low, but sufficient to prevent any symptoms of subacute scurvy. Hess emphasized that often children (with no scurvy symptoms) are irritable, slightly retarded in growth, and lacking in stamina, these conditions disappear when they are given orange juice or other food that provides vitamin C. Hopkins (of Cambridge University) investigated the diet in an English boys' school, where in the winter term there were complaints of listlessness and irritability, numerous minor illnesses, and low standards of work among the students. He found no uncooked foods, and practically no green vegetables in the diet, and learned that a shop where the boys had previously

Figure 69. Healing scurvy. Deposition of inorganic salts causes membranes about the bones to show up unusually plainly in this x-ray picture. Note how these membranes have floated loose due to inflammation and exudate about the joints, a condition characteristic of scurvy. (Courtesy of Dr. J. G. Coffin, New York City.)

A

B C

Figure 68 Scurvy A, The infant becomes irritable when handled B, Characteristic position, with legs flexed at hips and knees, and thighs externally rotated C, Gums are swollen and boggy (Cecil-Conn The Specialties in General Practice, 2nd Edition)

to elapse before the potency of these foods was explained as due to the presence in them of a specific substance known as a vitamin.

Symptoms of acute scurvy (caused by prolonged lack of vitamin C) are *swollen and bleeding gums, loose teeth, soreness and stiffness of joints, fragile bones, hemorrhages under the skin* and elsewhere, *loss of weight*, and *great muscular weakness*, leading to death Acute scurvy presents such a dramatic picture of degeneration in many body tissues (teeth and gums, blood vessel walls, bones, cartilage, and muscle tissues) that it is not difficult to recognize As these severe symptoms are prevented by taking even moderate amounts of fresh or cooked fruits and vegetables, "full-blown" scurvy is very seldom encountered now.

EFFECTS OF MODERATE LACK. A condition with less severe symptoms, known as *subacute* or *latent scurvy*, still occurs among infants fed almost exclusively on heat-treated milk or cereal gruels, in districts (such

water. It is the most unstable of all the known vitamins, as it is *easily oxidized*, by the loss of two hydrogen atoms per molecule, to a substance called dehydro-ascorbic acid. Although not itself biologically active, dehydro-ascorbic acid can be readily converted in the body (by reduction, adding hydrogen) to ascorbic acid. Thus both the ascorbic acid and the dehydro-ascorbic acid in foods contribute to their vitamin activity in the body. In living plant and animal tissues, thus oxidation-reduction between the two substances is *reversible,* although there is some destruction of the vitamin, presumably in performing its normal functions in nutrition.

In foods (outside the body), when the ascorbic acid is oxidized on exposure to air, there may be destruction of the biologically active substances and loss of more or less vitamin potency. The oxidation of ascorbic acid in foods is hastened by the enzymes present in raw fruits and vegetables, by heat, by alkalis, and by catalysts such as copper (use of copper kettles). Its destruction is slowed down in foods that are acid, by refrigeration, and above all by protection from exposure to air.

Chemical methods for the determination of ascorbic acid in foods, blood plasma, urine, and animal tissues are based on the fact that it is readily oxidized. In being oxidized, it will reduce certain colored dyes to colorless substances. The amount of the "unknown" required to decolorize a known quantity of the dye serves as a measure of its vitamin C content. Another test measures dehydro-ascorbic acid by the depth of color developed in its reaction with a certain organic compound.

Uses of Ascorbic Acid in the Body

Although the manner in which ascorbic acid functions in metabolism is yet to be explained, it is probably through its instability, its property

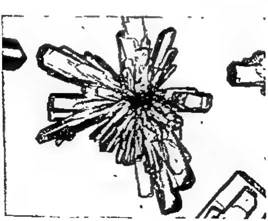

Figure 71. Photomicrograph showing crystalline structure of pure ascorbic acid. (Courtesy of Merck and Company.)

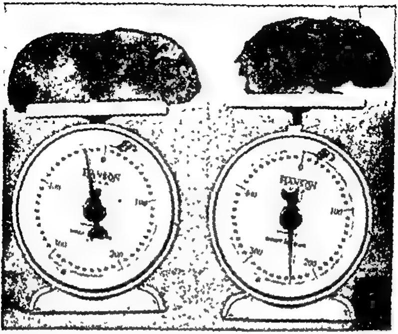

Figure 70 Stunting of growth due to lack of vitamin C The guinea pig at the right, which had a vitamin C–deficient diet, was in poor condition and weighed only 234 gm The guinea pig at the left, on the same diet plus orange juice, weighed 473 gm (Courtesy of Dr. J G Coffin, New York City)

bought fruit "on the side" had been closed some time before. On introduction of a liberal amount of fresh fruit into the diet, the boys were restored to normal disposition, health, and standards of work and play. Two of these observations on the benefits of larger amounts of this vitamin than are needed to prevent even symptoms of subacute scurvy were made before the vitamin had been chemically identified.

Chemical Identification and Properties

In 1932, Dr C C King of Pittsburgh (later head of The Nutrition Foundation in New York) and the Hungarian scientist Szent-Gyorgyi almost simultaneously obtained pure preparations of this substance, the former obtaining it from lemons and the latter from red peppers (also from adrenal glands) King announced, and Szent-Gyorgyi quickly confirmed, this substance to be a relatively simple organic acid with six carbon atoms in each molecule Its chemical structure is somewhat similar to that of the simple sugars, which also are built on a chain of six carbon atoms King gave it the name of *ascorbic acid*, indicative of the fact that it is a preventive of scurvy (*the adjective from scurvy is scorbutic*) After its chemical structure was known, it was soon possible to make this vitamin (from several six-carbon sugars) in the laboratory.

Ascorbic acid is a *white, crystalline solid*, which is readily *soluble in*

In addition to the role of ascorbic acid in normal maintenance of the above types of tissues, emphasis has recently been laid on the relation of ascorbic acid to the repair of injured tissues or to the *healing of wounds* and severe burns Both animal and human studies[3] indicate that a sufficiently low dietary intake of this vitamin results in delayed healing and less strength of the healed wound, whereas administration of extra ascorbic acid after operations promotes sound healing of wounds It seems reasonable that vitamin C, which is known to be essential for formation of substances that cement cells together and of tendrils of connective tissue, would function in the reknitting of tissues in wound healing

Vitamin C also functions, in some little understood way, in *protecting the body against infections and bacterial toxins* Menton and King[4] fed guinea pigs graded amounts of ascorbic acid, and found that those which received lower intakes of this vitamin suffered greater injury (loss of weight, tooth damage, etc) from repeated doses of diphtheria toxin, even though they showed no signs of scurvy Others have shown that guinea pigs on limited vitamin C intake succumb to inoculations with different strains of bacteria which have little or no effect upon animals that received liberal quantities of this vitamin The lowered resistance to infections in infants with scurvy is notable It would seem that ascorbic acid either unites with toxins to form nontoxic substances (and is excreted in this combined form), or is in some way destroyed in its action on the toxins At any rate, infections are known to increase the need for this vitamin and to rob the tissues of any reserve stores of it Hence, liberal intakes of vitamin C are thought to be helpful in enabling the body to combat infections There have also been experiments which suggest that vitamin C may have value in preventing muscular soreness after exercise[5] and that depletion of the body stores (2 months) leads to lower physical efficiency,[6] although extra doses of this vitamin given to persons on a normal, adequate diet exert no benefit on their muscular stamina

There is evidence that ascorbic acid acts in several ways to facilitate chemical changes which are vital to normal metabolism For instance, deficiency of it leads to increased up-take of oxygen both in the intact animal and in excised tissues [7] It has also been shown[8] that this vitamin is needed by animals for the normal metabolism of the amino acids, tyrosine and phenylalanine, while Levine and co-workers[9] have demon-

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[5] Johnson, R E , *et al*, J Nutr , 29, 155, 1945

[7] Stotz, King, *et al* , J Biol Chem , 122, 407, 1938, Fidlar, Sheppard, and McHenry, Biochem J , 33, 344, 1939

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of being reversibly oxidized and reduced, that it plays some part vital to the welfare of cells and tissues throughout the body. As hemoglobin and other iron-containing pigments with a unique function in the body are capable of alternately taking on and giving up oxygen (reversible oxidation-reduction), so ascorbic acid is able to alternately lose and take on hydrogen It thus can act as a "hydrogen carrier," and as such it may have an essential role in the metabolism of carbohydrates or proteins, or both. Whatever the explanation, the widespread tissue damage seen in scurvy makes it apparent that this vitamin is needed by many kinds of tissue, and hence its role would seem to be a fundamental one common to many tissues

At present, we get our clues as to its function or functions chiefly from the symptoms seen in scurvy and hence caused by its lack in the body So many apparently unrelated tissues show damage that it is only confusing to attempt to enumerate them in detail The main types of tissue showing marked damage in scorbutic animals may be grouped under three heads·

(1) *Connective* and supporting tissues, such as cartilage at joints, intercellular tissue in blood vessel walls, gum tissues about the teeth, etc ,
(2) Cells in the *internal parts of bones and teeth* (bone marrow and dentine), responsible for the maintenance of these bony tissues,
(3) *Muscular* tissues

The results of damage to these three kinds of tissue is evidenced in scurvy in the following ways blood vessel walls become more fragile and are likely to "spring a leak" (hemorrhage), there is damage to cartilage in the growing ends of bones and bones may slip apart at the joints due to lack of supporting cartilage, the bones themselves become less strong through degeneration of the bone matrix and loss of calcium, there is swelling and bleeding of gums and loosening of teeth, finally, degeneration of muscle fibers (including those of the heart) leads to great muscular weakness and even death Anemia, often seen in scurvy, may be due to degeneration of the cells in the bone marrow that are charged with formation of new red blood cells, to loss of blood by hemorrhage, or both

The lessened strength of the blood vessel walls, as evidenced by tendency to hemorrhages from small blood vessels under the skin (when suction or pressure is applied), has been used as a test for low-grade lack of vitamin C, the so-called *"capillary fragility test"*[1] Likewise damage to the odontoblasts (cells responsible for maintaining normal condition of the dentine in teeth) is one of the earliest signs of ascorbic acid deficiency in guinea pigs, *changes in the internal structure of the teeth* have been demonstrated microscopically in guinea pigs in less than a week after deprivation of vitamin C.[2]

[1] Gothlin, Skan Arch Physiol, 61, 225, 1931, and later papers
[2] Fish, E W., and Harris, L. J, Brit Dent J, 58, 3, 1935, Crampton, E W, J Nutr, 33, 491, 1947.

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[9] Levine, Marples, and Gordon, J Clin Invest , 20, 199, 1941

strated that the same is true in premature infants; thus vitamin C must have some part (perhaps in an enzyme) in metabolism of proteins, and there are indications that more of it may be needed when larger quantities of protein are included in the diet[10] The adrenal glands are known to contain more ascorbic acid than most other tissues, and this substance must be in some way concerned in the secretion of hormones of the adrenal cortex, since the increased secretion of these hormones has been shown to be associated with a sharp decrease in the ascorbic acid (and cholesterol) content of the glands[11] Evidence has been produced[12] which indicates that there is some interrelation between vitamin C and the role in metabolism of folic acid, one of the B-complex vitamins Just how or why ascorbic acid is concerned in so many and such varied chemical changes that are parts of normal metabolism in the tissues is not yet known, but enough is known to establish it as an important substance for body welfare.

Ascorbic Acid in Human Metabolism

Man, monkeys, and guinea pigs are entirely dependent for vitamin C upon the amounts contained in their food, since they cannot make this substance in their bodies. All other animals need ascorbic acid but can build it in their bodies (either from d-glucose, d-galactose, or perhaps from intermediate products of sugar metabolism), as is evidenced by the fact that it is present in their tissues at a level comparable to that found in man when the food supplies this vitamin liberally. The discussion in the following paragraphs will be limited to ascorbic acid metabolism in man

Vitamin C taken in the food is absorbed into the blood stream, chiefly from the small intestine, within a few hours after eating The level of ascorbic acid in the blood plasma is increased only temporarily, since this substance is taken up by the tissues, and any excess is excreted promptly by the kidneys Intravenously injected vitamin C is excreted within 1–3 hours Although there is limited ability to store ascorbic acid in the body, it is present in higher concentrations in glandular tissues, especially in the adrenal glands The amount of this substance in the body tissues depends on the quantity in the food, and on the rate at which it is destroyed in and excreted from the body

Under normal conditions, higher levels of daily intake of ascorbic acid result in increased amounts of it both in the body and in the urine Conversely, low levels of vitamin C in the blood and urine indicate that the daily diet provides little of this vitamin If a vitamin C–poor diet has been long continued, the tissues become unusually low in, and are said to be "unsaturated" as to, vitamin C When higher intakes are given

Am J Digest Dis 10 390, 1943

74, 52, 1950, May, C D, Clin Invest, 30, 639, 1951.

et al,

to such persons, the tissues will take up more vitamin C and abnormally low amounts will be excreted in the urine If high intakes of vitamin C are continued until the tissues have become "saturated" with vitamin C, urinary excretion will then rise decidedly since the excess is excreted through this channel This knowledge of the normal courses of vitamin C in the body has been established by experiments too numerous to quote

Tests to determine whether or not an individual has been getting enough ascorbic acid in his diet for good nutrition ("nutritional status" tests) are based on the above facts One test is to determine the *level of ascorbic acid in the blood* under the usual dietary conditions Another way is to inject a sizable dose of ascorbic acid, after which the level of it in the blood is determined—the more unsaturated the tissues are as to vitamin C, the less of the injected dose will be left in the blood A third form of test consists in following the amount of *ascorbic acid excreted in the urine* after a considerable quantity of this substance has been taken by mouth If the diet has been deficient in vitamin C, the tissues will take up most of the quantity fed, so that there will be little excess to appear in the urine, and vice versa

The results of such tests, made on many persons during recent years, make it clear that a large proportion of those tested had been getting less than "optimum" amounts of vitamin C in the diet The number considered "deficient" will depend on how high a standard is set as normal There is no evidence that *saturation* of the tissues with ascorbic acid is *essential* to health, but the tendency is to consider that larger intakes of this vitamin, which make for higher concentrations of it in the body, are desirable from the standpoint of health

Surveys[13] on the level of ascorbic acid in the blood plasma of school children during months when fruits and vegetables are scarce show that one half to two thirds of the apparently healthy children were receiving diets below optimum in vitamin C, while in approximately one third the shortage was of a degree dangerous to health Other workers[14] claim that deficiency of this vitamin (as judged by saturation tests) is widespread among aged persons Several surveys on the ascorbic acid status of college students, which are listed in the supplementary reading at the end of this chapter, indicate that considerable numbers are at least on the borderline of adequacy as to vitamin C intake and level in the body.

Requirement and Standard Allowance

The *minimum requirement* of adult men was studied on ten volunteers in Britain in 1944–46, on a special diet that supplied only 0 1 mg ascorbic acid per day[15] The ascorbic acid of the blood plasma soon sank

[13] Minot, A S, Dodd, K, Keller, M, and Frank, H, J Pediatrics, 16, 717, 1940, Holmes, F E, Cullen, G E, and Nelson, W E, J Pediatrics, 18, 300, 1941, Murphy, E, J Nutr, 21, 527, 1941

[14] Rafsky, H A, and Newman, B, Am J Med Sc, 201, 749, 1941

[15] British Med Res Council, Special Report No 280, "Vitamin C Requirements of Human Adults," 1953

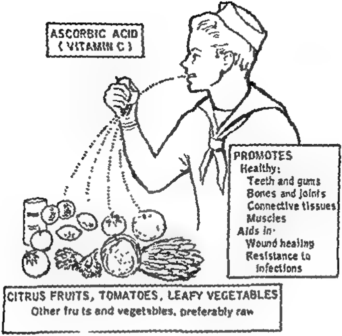

Figure 72

to low levels, but gum changes did not appear until the subjects had been on the diet for 26 weeks It was found that 10 mg. of ascorbic acid was sufficient to prevent scurvy or to cure it in cases where it was allowed to develop. To provide a margin of safety, the British committee suggested 30 mg as a satisfactory daily allowance for adults and the Canadian *recommended allowance* for vitamin C is placed at the same figure.

Although this level of vitamin C intake will undoubtedly maintain adults in health and is a practical one in countries where fresh fruits and vegetables are not abundant, the Food and Nutrition Board of the U. S National Research Council felt that a higher intake would be better. It is perhaps unrealistic to aim for an intake high enough to maintain "saturation" of the body with ascorbic acid,[16] and besides, no one has shown yet that any increased health benefits accrue from this goal A moderately liberal intake, however, would lead to a higher level of this

corbic acid daily for a woman (58 kg body weight) and 75 mg for a 70 kg man This should provide a safe margin for individual variations in body needs

Children (especially teen-agers) and pregnant or lactating women have a higher need for vitamin C than normal adults The standard allowances for girls over 12 years of age is 80 mg daily, for boys 12–20 years, 90–100 mg For the last three months of pregnancy 100 mg daily is recommended, 150 mg per day for lactating women It may require special planning to provide such quantities of this vitamin in the diet, particularly for teen-age girls

Distribution in Foods

For vitamin C we are dependent almost entirely upon *fruits* and *vegetables*, and those that may be eaten *fresh* and *uncooked* are the best sources Milk contains small amounts of vitamin C but is an undependable source, especially if pasteurized Much of the vitamin C in meats is destroyed in cooking, eggs, cereal grains, sugar, and fats, nuts, dried legumes, and dried fruits contain either very little or none at all

It will be seen from Table 11 (p 212) that certain kinds of fruit and vegetables are unusually rich in ascorbic acid Citrus fruits, strawberries, and cantaloupe lead the fruits in vitamin C content Green leafy vegetables, peppers, broccoli, and cauliflower have such a high content of vitamin C that they are practically as good sources as the aforementioned fruits, even after cooking Raw cabbage or turnip, salad greens, and tomatoes (either fresh or canned) are very good sources Potatoes will contribute considerable amounts when eaten in large quantities Most cooked and canned vegetables and fruits provide some vitamin C, but in smaller and more variable amounts than the corresponding fresh foods

It should be understood that there is considerable variability in the ascorbic acid content of fruits and vegetables, and that the figures given in Table 11 represent only approximate mean values It has been shown that vitamin C content of plant foods varies greatly with different varieties of the same plant, with soil and climate, and especially according to the amount of exposure to sunlight and the degree of ripeness of the fruit Maynard and co-workers[18] established that variations in degree of exposure to light while on the vine exerted the greatest influence on the ascorbic acid content in tomatoes Van Duyne[19] found in freshly harvested vegetables (per 100 gm edible portion) such wide variations in ascorbic acid content as the following broccoli, 91–172 mg, carrots, 39–160 mg, mustard greens, 107–142 mg, peas, 19–41 mg Different varieties of apples and oranges have been found to vary considerably in vitamin C content, Sherman[20] gives the range within which the final

[18] Hamner, Bernstein, and Maynard, J Nutr, 29, 85, 1945

[19] Van Duyne, *et al*, J Am Dietet Assoc, 21, 153, 1945, Expt Sta Rec, 95, 602, 1945

[20] Sherman, H C, CHEMISTRY OF FOOD AND NUTRITION, p 352 Macmillan, 8th ed, 1952

Table 11. Fruits and Vegetables as Sources of Vitamin C*

Food	Per 100 grams, raw, E P. Ascorbic Acid	Per average serving: Size of serving	Per average serving: Ascorbic Acid
Fruits, fresh:	mg		mg.
Strawberries	60	10 large strawberries	60
Oranges (or juice)	49	6 oz orange juice (small glass, fresh)	90
Lemons (or juice)	50	4 oz lemon juice (½ cup sc., 7 tbsp)	56
Grapefruit (or juice)	40	6½ oz canned juice or ½ med large grapefruit, 4¼ in diameter.	72
Cantaloupe	33	½ cantaloupe, 4½ in diam	50
Pineapple	24	⅔ cup pineapple, cubed	24
Berries (except strawberries and blueberries)	23	⅔–¾ cup of berries	23
Honeydew melon	23	¼ melon, 5 in diam.	23
Blueberries	16	⅔ cup blueberries	16
Avocados	16	½ avocado, 4 in. long	16
Bananas	10	1 medium banana, or 1 cup slices	15
Cherries	8	½ cup pitted cherries	8
Peaches	8	1 medium-large peach	8
Apricots	7	Apricots, 2-3 med, raw	7
		4 halves, canned	4
Apples, Grapes, Pears, Plums, Watermelon	4–6	1 medium or 2-3 small fruits (22-24 grapes)	5
		Watermelon, 1 slice, 1½ in thick, 6 in diam (600 gm)	36
Vegetables:			
Turnip greens	136	½ cup cooked turnip greens (73 gm)	33–44
Peppers, green	115–120	1 medium pepper shell cooked	64
Broccoli		⅔ cup cooked broccoli.	74
Kale		⅔ cup cooked kale	37
Mustard greens, Collards	94–102	⅔ cup cooked mustard greens or collards	42
Brussels sprouts		6 avg Brussels sprouts, cooked (70 gm)	33
Cauliflower	69	½ cup cauliflower, cooked (60 gm)	17
Spinach	59	½ cup cooked spinach (90 gm)	27
Cabbage	50	½ cup cooked cabbage (85 gm)	16–27
Chard, Dandelion greens	34–38	½ cup cooked chard or dandelion greens	13–15
Beet greens		½ cup cooked beet greens	11
Rutabagas		½ cup cooked rutabagas	17

* Figures for both raw and cooked foods are from U. S. Dept. Agric Handbook No. 8, "Composition of Foods—Raw, Processed, Prepared," 1950

Table 11 (Continued)

Food	Per 100 grams, raw, E.P. — Ascorbic Acid	Per average serving — Size of serving	Per average serving — Ascorbic Acid
Vegetables (cont.)	mg.		mg.
Asparagus		6 med. stalks asparagus, cooked (100 gm)	23
Beans, lima, green	28–33	½ cup cooked lima beans (80 gm)	12
Okra		4 pods cooked okra (45 gm)	9
Turnip, white		⅔ cup cooked turnip, cubed (100 gm)	18
Peas, green	26	½ cup cooked green peas (80 gm)	12
Radishes		3 radishes, 1 in. diam., raw (28 gm)	7
Onions, young, green			
Sweet potatoes	22–24	1 medium sweet potato, baked or boiled in skin (120 gm)	28
Tomatoes (or juice)		1 medium *raw* tomato (150 gm)	35
		½ cup canned or cooked tomato	20
Beans, string, green		⅔ cup cooked string beans or ½ cup cooked parsnip (80 gm)	9–12
Parsnips		½ cup cooked summer squash	11
Squash, summer	17–19	2 large or 4–5 small green lettuce leaves, *raw* (50 gm)	9
Lettuce, green			
Potatoes		1 medium potato, cooked in skin (100 gm)	15-17
Beets		2 small or ½ cup diced beets, cooked	4–5
Corn, sweet	9–12	½ cup canned corn or 1 med. ear, cooked	5–8
Onions, mature		1 large or 2–3 small onions, cooked	6
Lettuce, head		⅙ lg. head lettuce (bleached, 50 gm)	4
Cucumbers	8	½ med. cucumber, *raw*, or 8 slices (50 gm)	4
Squash, winter		½ cup cooked winter squash (100 gm)	5–7
Celery		2 stalks or hearts of celery, *raw* (50 gm)	4
Carrots	5–7	½ cup cubed carrots, cooked (75 gm)	3
Eggplant		½ cup cooked eggplant (100 gm)	3

average will probably be found—for medium varieties of apples, 5–8 mg., and for oranges, 49–56 mg. ascorbic acid per 100 gm. Even allowing for variations, it can be seen that certain fruits and vegetables are much richer in this vitamin than others.

Further variations in the vitamin C content of foods as they appear on the table must be expected because of losses of this vitamin during *storage, processing* (canning or drying), and *cooking*. Leafy vegetables (with large surface area) lose more of the vitamin on storage than do root vegetables or tubers, refrigeration during storage will reduce losses,

and in markets more of the vitamin is retained if vegetables are kept in crushed ice than if they are kept in a refrigerator. In preparation for canning, quick freezing, or drying, a brief blanching with steam favors retention of the vitamin, because it destroys the enzymes that hasten its destruction in raw foods There is least loss of vitamin C when foods are preserved by quick freezing, most loss occurs when they are preserved by drying, especially if they are exposed to sunlight in the process. Commercially canned foods may compare favorably in vitamin C content with home-cooked products if the fruit or vegetable reaches the cannery fresh from nearby fields and is heated quickly in vacuum-sealed cans. Since vitamin C is water soluble, considerable amounts of it may be lost in the liquid in which the food was canned, if this is discarded. In drying fruits, sulfuring before drying and rapid drying (away from sunlight) favor retention of the vitamin content, but dried fruits cannot be counted on as a source of much vitamin C.

In *cooking* foods, the loss in vitamin C content depends on numerous factors, including the nature of the food, its reaction (acid or alkaline), the period and degree of heating, and especially the extent to which the food is exposed to water and to air in the cooking process Retention of the vitamin is favored by cooking by steaming or in small amounts of water or by pressure cooker (shortened time), cooking with peel left on or in large pieces, cooking with as much exclusion of air as possible (tightly covered vessel or pressure cooker) Increased losses of the vitamin result from adding soda, any contact with copper or iron in preparing or cooking the food, or from mashing the food and leaving it in a hot place or exposed to the air. The influence of various factors on retention of ascorbic acid during cookery is illustrated by the figures on *potatoes*[21] given here

Preparation, and Cooking Method	*Per Cent of Vitamin Retained*
Whole, in skins, covered pan, 750 cc water, 40 min	90
Whole, pared, covered pan, 750 cc. water, 40 min	[illegible]
Whole, pared, then mashed, 750 cc. water, 40 min	47
Pared and quartered, only 450 cc water, 23 min	71

Studies have recently been published[22] which show the effect of cooking methods on ascorbic acid retention and color differences in broccoli and some other vegetables.

Conserving Vitamin C in Foods

It is foolish to allow vitamin C, which is valuable for health, to be lost before foods are served on the table As this is the most easily destroyed of the vitamins (and the one needed in largest quantities), its

[21] Figures from VITAMIN AND MINERAL CONTENT OF CERTAIN FOODS AS AFFECTED BY HOME PREPARATION, U S Dept Agric, Misc. Pub. No 628, 1948

[22] Sweeney, J P, *et al*, J Am Dietet Assoc, 35, 354, 1959 Gordon, J, and Noble, I, ibid, 35, 578, 1959.

conservation presents a special problem. Reasons for the following special *precautions* in handling fresh fruits and vegetables should be self-evident if one keeps in mind that vitamin C is water soluble and easily destroyed by oxidation, while heat, alkaline reaction, and, above all, exposure to air hasten its destruction

Buy fresh fruits and vegetables in small enough quantities so that they will be used promptly, keep them at low temperature (in refrigerator, if possible)
Prepare them (paring and cutting up) immediately before they are to be cooked or served raw, do not let them stand in water or exposed to air before cooking, serve promptly, *do not keep hot for long* (or reheat) before serving
Cook in as small a quantity of water and for as short a time as feasible, cook by steaming, or broiling (instead of boiling) and with "skins" left on when possible, keep cooking vessels tightly covered
Never add soda in cooking vegetables or cook in copper container (presence of either alkali or copper hastens vitamin destruction)
Do not allow "quick-frozen" foods to thaw out before cooking, keep them in refrigerator and start cooking in frozen state in boiling water
Juices of fresh fruits are best prepared immediately before serving and slightly more vitamins (and minerals) are obtained if they are not strained However, acid juices (orange, grapefruit, tomato) may be left in a covered glass container in the refrigerator over night with little loss in vitamin C value, size container should be chosen so liquid will about fill it, with minimum of air left in over liquid

How to Get Standard Allowance of Vitamin C in Diet

The following general rules will safeguard the diet as to vitamin C

Take at least one food *raw* each day, preferably both a green salad and fresh fruit
Have one serving of *citrus fruit* or *tomato* daily (or other *rich* source of vitamin C)
Use other fruits and vegetables as freely as possible

Two servings of vegetables, besides potato, together with one serving of fresh fruit, may be counted on to furnish one third to one half of the daily quota of ascorbic acid for an adult (75 mg) The remainder of the quota should be provided by some food especially rich in vitamin C, such as citrus fruit or tomato A small (6 oz) glass of orange juice will furnish more than the daily adult quota of ascorbic acid, while the same quantity of tomato juice will provide less than half enough for the

Foods Which Will Furnish Various Amounts of Ascorbic Acid

(1) 50 mg Ascorbic acid	(2) 75 mg Ascorbic acid	(3) 100 mg Ascorbic acid
Any one of the following	All of the following	Either
3½ oz (½ c) fresh orange juice	Tomato, 1 sm fresh or ⅔ c canned	Orange juice 7 oz fresh or 8 oz canned (full glass)
5 oz (10 tbsp) canned grapefruit juice	Potato, 1 cooked	Or ⅔ c cooked broccoli and 6 oz canned tomato juice
10 oz (1¼ c) tomato juice, fresh or canned	Root vegetable, 1 average serving	
½ cantaloupe, 4½ in diam	Leafy vegetable, ½ c, cooked	
	Fresh fruit (not citrus), average serving	

day's need In a study on comparative costs of vitamin C in fruit and vegetable juices, Holmes and co-workers[23] found canned orange and grapefruit juices to be the most economical sources The frozen concentrated orange juice now on the market is also an excellent source, besides being very acceptable for flavor and easier to prepare than the fresh juice.

QUESTIONS AND PROBLEMS

1 From what materials was vitamin C first isolated as a pure substance? What type of a chemical compound is it? Why was the name ascorbic acid given to it? Where does it occur in nature? in the human body? What is the source of the pure ascorbic acid bought in tablet form at drug stores? Is it the same as naturally occurring ascorbic acid? How stable is the substance when kept in dry, solid form? in water solution with alkaline reaction? in acid solution? What other conditions affect its stability, and why?

2 Why was scurvy a very prevalent disease among crews on long sea voyages and early explorations? Why was it possible for Admiral Byrd recently to take men into the Antarctic for long periods without fear that any of them would succumb to scurvy? What foods, or other substances, were known to prevent or cure scurvy long before it was recognized that their efficacy in this respect was due to the presence in all of them of a definite compound that might be classed as a vitamin? Give the symptoms of acute scurvy and explain the widespread tissue damages in the light of one of the chief functions of vitamin C in the body, i e , the formation and maintenance of intercellular and connective tissue substances.

3 Why do men and guinea pigs develop scurvy when the diet is lacking in ascorbic acid, while dogs, rats, and other animals do not? Do plants need ascorbic acid, and if so, how do they get it? Give three characteristic symptoms of subacute or latent scurvy in infants, three symptoms in adults that indicate the diet has furnished too little vitamin C From consideration of the results of lack of this vitamin, what would you conclude are its main uses in the body?

4 Outline three tests that may be used to determine the level of ascorbic acid in the body, as an index of whether or not this vitamin has been supplied in adequate amounts by the diet If the ascorbic acid content of the blood plasma is below normal, does this necessarily mean that there is little or none of this substance in other body tissues? What test or tests will indicate the "degree of saturation," or extent of depletion, of the tissues with respect to ascorbic acid? How important for health is it that the level of ascorbic acid in the blood and tissues should be at least fairly high, and why?

5 What classes of foods contribute little or no vitamin C in the diet, at least in the condition in which they are eaten? What classes of

[23] New England J. Med , 225, 68, 1941

foods furnish the major part of the vitamin C intake? Consult Table 11 (pp 212–213) and list the five fruits and five vegetables richest in ascorbic acid in the raw state List the ten that have the next highest ascorbic acid content per 100 gm, either fruits or vegetables, in order of their relative vitamin C content when raw Rearrange these 20 fruits and vegetables in the order of the vitamin C contribution that will be made by an *average serving* of each, fruits raw and vegetables with average allowance for loss of vitamin C in cooking, as given in the final column of Table 11

6 What is the recommended daily allowance of ascorbic acid for a normal woman? for a teen-age boy? for a pregnant woman? Why is the need for this vitamin relatively higher in childhood? in pregnancy and lactation? If 10 mg ascorbic acid per day will protect an adult against scurvy, what is the use of taking 70 mg? Since foods that carry vitamin C are often fairly expensive and excess of it above body needs is excreted in the urine, is there any point in taking about twice the recommended allowance (150 mg) daily? Is a high level of vitamin C intake practical, considering cost and size of servings of foods needed to provide this vitamin in large amounts?

7 List five foods that will provide ascorbic acid at low or moderate cost Plan a day's diet, at low or moderate cost, that will furnish about 75 mg of ascorbic acid for an adult, following the dietary pattern given on page 197

8 Plan a day's meals for yourself with some food that is a good source of vitamin C in each meal Compute how many milligrams of vitamin C this diet will provide and compare with the standard allowance

9 Give rules for conserving vitamin C in foods during storage and preparation for the table

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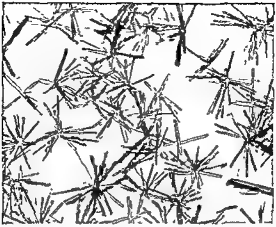

Figure 73. Photomicrograph of vitamin B_1, crystalline form (Courtesy of Merck and Company)

bon, hydrogen, oxygen, and sulfur, readily soluble in water and slightly soluble in alcohol Although it is much less sensitive to oxidation than ■ ascorbic acid (vitamin C), it may be destroyed by heating in solution, especially by prolonged heating at high temperatures, or in neutral or alkaline solution Synthetic vitamin B_1 ■ usually prepared in the form of a salt, thiamine hydrochloride, which is more stable than the free vitamin.

Effects of Lack of Vitamin B_1

BERIBERI Although beriberi was described in Chinese medical literature in times before Christ, its cause was not known to be related to the diet until early in the twentieth century It was eradicated from the Japanese navy by simple changes in diet instituted by Takaki in 1885, and in 1897 ■ Dutch physician in Java (Eijkman) showed that a similar disease appeared in fowls fed nothing but polished rice Working from these clues, numerous research workers in Java and the Philippines proved conclusively that human beriberi occurred on diets which consisted largely of polished rice, and could be prevented by the substitution of brown rice, whole barley, or dried legumes for part of the polished rice Still later, the beriberi-preventing substance was extracted from rice bran or yeast (it took half a ton of rice bran or a ton of yeast to yield about 1 gram of fairly pure vitamin), and these concentrated preparations were very effective in causing the disappearance of symptoms of beriberi in human beings (or of the similar disease, polyneuritis, in fowls). Beriberi was thus shown to be due to lack of a substance that is contained in the germ and outer coats of grains but ■ almost entirely absent in polished rice or highly milled cereals This substance came to be known as the "antineuritic" vitamin, vitamin B_1, or thiamine.

B-Complex Vitamins

THIAMINE (VITAMIN B_1)

THIAMINE (vitamin B_1) made its debut as a recognized "food hormone" or vitamin about 1911. Research led to the discovery of this vitamin from two entirely different angles: (1) as a preventive for the disease *beriberi*, which had occurred among rice-eating peoples of the Orient for centuries, and (2) as a water-soluble constituent of foods that is essential for *growth* of animals. Later this growth-promoting factor (found in wheat germ and protein-free milk) was proved to be identical with the anti-beriberi factor (obtained from rice polishings and yeast).

Chemical Identification and Properties

The first pure preparation of this substance was secured in 1926, but establishment of its chemical identity was not complete until 1936, when Dr. R. R. Williams (formerly in the Philippine Bureau of Science and later head of the Bell Telephone Laboratories) first made it synthetically and gave it the name *thiamine*.

Thiamine is a crystalline substance, made up of the elements car-

tissue damage that occurs in beriberi, due to lack of thiamine, makes us realize that this vitamin must play an important role in normal nutrition

It is present in most plant and animal tissues. Plants and some microorganisms are able to synthesize vitamin B_1, which is needed to promote their growth. Bacteria in the intestinal tract of rats, cattle, sheep, and to some extent also in man, can make this vitamin, but for the most part man and other animals must obtain it preformed in food. In human beings, thiamine is present in small amounts in practically all tissues and in somewhat higher concentration in such organs as the heart, liver, and kidneys As with vitamin C, there is limited ability to store vitamin B_1 but it is found in slightly greater quantities in the tissues when the diet has provided liberal amounts of it, and tissues are depleted of their normal content on a diet deficient in vitamin B_1

Thiamine was early shown to be essential for *growth* of animals,

Figure 76 Case of dry beriberi, showing atrophy of the muscles due to paralysis of the legs (Courtesy of Herzog and the Philippine Journal of Science)

Figure 74 Characteristic attitude of pigeon with polyneuritis (avian beriberi) after three weeks' feeding with a diet of "polished" rice The pigeon was used year after year as a class demonstration, and the extreme effect passed off within a few hours after feeding foods rich in vitamin B_1 (Morse, APPLIED BIOCHEMISTRY.)

Figure 75 Pigeon shown in Figure 74 three hours after feeding substance rich in B_1 (rice polishings, yeast, etc) Recovery seemed to be complete in twelve hours (Morse, APPLIED BIOCHEMISTRY)

The *symptoms* of beriberi are numbness or tingling in toes and feet, stiffness of ankles and absence of "ankle jerk" reflex, cramping pains in legs, difficulty in walking, and finally paralysis of legs with atrophy of leg muscles In later stages various nerves in the upper part of the body may be affected, and disturbances of heart function are common. In the form known as *wet* beriberi dropsical bloating or edema (especially of legs) is a complicating factor.

Functions of Thiamine in Normal Nutrition

American diets provide enough vitamin B_1 so that beriberi is practically never seen in this country, although a good many diets may provide less than optimal amounts and symptoms of low-grade deficiency are not uncommon, especially at times of body stress such as growth, pregnancy, after infectious diseases or surgical operations. The extensive

fants from five to ten months old. The diet of these babies had been considered adequate, and they received orange juice and cod liver oil (for vitamins C, A, and D). Growth was accelerated and general health much improved when wheat germ or yeast extract, or synthetic thiamine, was given either to the mothers of nursing babies or directly to the child.[1] Neither cow's nor human milk is a very good source of this vitamin, the amount in breast milk depends on the sources of vitamin B_1 in the maternal diet and less than half of the vitamin fed is transferred to the milk.[2] Hence the safest course is to give the vitamin directly to the baby. It has been recommended[3] that "just as regularly as orange juice and cod liver oil are prescribed one should also prescribe a substance rich in vitamin B_1 for the infant dietary." Older children have also been shown to make better growth when the diet was reinforced by foods rich in this vitamin.

Thiamine also plays a part in promoting *appetite* and better functioning of the *digestive tract*, effects that have an indirect influence in promoting growth. Cowgill[4] showed that dogs fed a vitamin B_1-deficient diet soon refused to eat and that, at the same time, there was a marked decrease in the muscular tone and motility of the stomach and intestines, either giving thiamine by mouth, separate from the food, or injecting it into the blood, restored appetite for the food that the animal previously refused to eat and caused digestive functions to return to normal. These findings have since been confirmed by many investigators, both for other animals and for man.[5] The emptying time of the stomach and intestines has been shown to be nearly twice as slow in thiamine-deficient animals as in normal ones, and this vitamin has been of assistance in relieving stubborn cases of constipation. However, most authorities agree that the specific effect of vitamin B_1 on appetite is exerted only when there has been a deficiency of it in the diet and then only to the extent of restoring *normal* appetite, large quantities of the vitamin will not promote a voracious appetite, and other factors may be responsible for loss of desire for food.

Of foremost importance is the part thiamine plays in the life processes of individual cells throughout the body. Most of the energy for the life processes of body tissues comes from the oxidation of carbohydrate, which takes place gradually through the formation of intermediate products and requires enzymes[6] to bring about or catalyze each step of the intricate process. Some of the enzymes require coenzymes

[1] Hoobler, B. R., J.A.M.A., 91, 307, 1928, Clements, F. W., M. J. Australia, 1, 12, 1942, Knott, E. M., *et al.*, J. Home Econ., 35, 377, 1943.

[2] Review, "Thiamine in Human Milk," Nutr. Rev., 1, 270, 1943.

[3] Hoobler, reference cited.

[4] Cowgill, G. R., Rosenberg, H. A., and Rogoff, J., Am. J. Physiol., 96, 372, 1931.

[5] Schultz, F. W., and Knott, E. M., "Effect of Varied Vitamin B_1 Ingestion upon the Appetite of Children," J. Nutr., 15, 411, 1938.

[6] A fuller description of enzymes and their mode of action is given in connection with the digestive enzymes (Chapter 17, pp. 360–362).

Figure 77 Patient before and after treatment for thiamine deficiency *A*, swelling of the legs and marked pitting edema in the ankle region, *B*, ten days after initiation of thiamine therapy, during which the patient lost 40 pounds in weight Presumably this weight loss was due to loss of fluid since the general nutritive state was greatly improved (Spies, REHABILITATION THROUGH BETTER NUTRITION)

Figure 78 Effects on growth of feeding four different levels of thiamine (From experiments by Dr. Bertha Bisbey)

and later was established as needed for successful *reproduction* Growth

need and, since it is freely soluble in water, most of the thiamine intake not required for day-to-day uses is ***excreted in the urine.***

The biochemical function of the thiamine-containing coenzyme [illegible] to enable an enzyme called carboxylase to split off carbon dioxide from pyruvic acid, after which the remainder of the molecule (acetic acid or acetate) can be converted to the end products of oxidation, carbon dioxide and water The coenzyme, called cocarboxylase, [illegible]

Measurement of Requirement and Nutritional Level

It is impossible to give any exact figure for the vitamin B_1 need of adults, since the amount required will vary according to size, degree of activity, dietary habits, and individual differences in its utilization from food As this vitamin takes part in the metabolism of carbohydrate, more of it will be needed when carbohydrate metabolism is high ***Persons who do muscular work*** burn up more fuel foods and usually take much of this extra fuel in the form of starchy foods, hence they need more thiamine than those who are muscularly inactive The proportion of starchy foods and sweets in the diet also varies with different people. The requirement for vitamin B_1 is often stated in terms of the caloric intake (so much for every 1000 calories) or of the non-fat calories of the diet, with more fat and a lower proportion of calories from carbohydrate, less thiamine is needed ***Growing children*** have higher fuel needs, and so higher vitamin B_1 needs, per unit of body weight than adults Women in the second half of ***pregnancy*** have slightly increased need for thiamine, and ***nursing mothers*** should have approximately one and one-half times as much as at other times

Then, too, there is considerable difference of opinion as to what constitutes an adequate supply of this vitamin Some investigators believe that an intake just sufficient to ward off any symptoms of mild deficiency is enough, others believe that a more liberal allowance is desirable and will yield benefits in better health The level of ***minimum requirement*** has been variously set[8] between 0 23 and 0 65 milligrams per 1000 calories, which would mean that a sedentary man or woman on an average diet, furnishing 2500 calories, according to the lower figure should have a total of 0 5 mg, and at the higher figure 1 5 mg thiamine daily Wilder[9] has stated that 1 2 mg daily is needed to ensure health and that, to allow for failure of all the thiamine in foods to be absorbed from the intestine, 2 0 mg daily should be provided for

[8] Elsom, [illegible] O, *et al*, Am J M Sc, 203, 569, 1942, Melnick, [illegible], J Nutr, 24, 139, 1942 [illegible]
1943 [illegible]
69, 7 [illegible]
vesti [illegible]

[9] Wilder, R M, Arch Int Med, 14, 2189, 1941.

to render them active, or capable of bringing about a certain chemical change. Thiamine has been shown to be the *active part of a coenzyme* which is necessary for the further oxidation of pyruvic acid, one of the *intermediate products* of carbohydrate oxidation. Hence it constitutes an essential link in the chainlike process of passing along oxygen to the tissues and must be provided for the complete *oxidation of carbohydrate.* As this thiamine-containing coenzyme aids in the oxygen uptake of all kinds of tissues, an insufficient supply of thiamine may result in faulty functioning of various tissues, and an extra supply of this vitamin may cause quick restoration of normal functioning. Nervous tissue is especially dependent upon carbohydrate oxidation for its life processes and so is one of the first to show effects of thiamine lack in faulty functioning.

Thiamine has been called "the morale vitamin," since the earliest signs of its lack show in a lowering of nervous stamina. Scientific studies[7] of people who volunteered to consume a diet moderately low in vitamin B_1 demonstrated that, after a very short time on such a diet, the subjects became *depressed, irritable, lacking in ability to concentrate* on and take interest in their work. In three to seven weeks, such symptoms as *fatigue, lack of appetite, loss of weight, constipation,* muscle cramps, and various *nervous pains* appeared. The subjects promptly recovered normal health and morale when given larger amounts of thiamine. Freely chosen human diets, which are low in thiamine content, often furnish too little of other B-complex vitamins as well, and in such cases several of the B vitamins may be needed before relief from all deficiency symptoms is obtained.

Thiamine in the Body

This substance, which is so essential for health, exists in raw and unrefined foods in amounts that range from 2 parts per 10 million to 14 parts per million. Its activity in the body is dependent on the fact that it undergoes *reversible oxidation-reduction,* and this in turn is probably due to the *sulfur-containing group* in its molecule. There are only two vitamins that contain sulfur, thiamine and biotin, another of the B-complex group.

Thiamine in the food is absorbed from the intestine and carried in the blood to the tissues. *Limited* quantities of it may be stored in the liver, kidneys, heart, muscles, and brain, but only enough to maintain optimum functioning of body tissues for a very short period, so that fresh supplies are needed daily. The thiamine-containing substance (coenzyme) which assists in oxidation of carbohydrate is made by tissue cells and carried in the blood chiefly in the nucleated white cells, with free thiamine in the plasma. The tissues take up only as much as they

[7] Melnick, D., *et al.*, J. Nutr., 18, 593, 1939; Jolliffe, N., *et al.*, Am. J. M. Sc., 198, 198, 1939; Williams, R. D., *et al.*, Arch. Int. Med., 69, 721, 1942, and 71, 38, 1943; Hulse, M. C., *et al.*, Ann. Int. Med., 21, 440, 1944.

as to vitamin B_1 If the diet has been deficient in this vitamin for a considerable period, there will be abnormally low amounts of thiamine in the urine, as well as decreased amounts of the thiamine-containing enzyme (cocarboxylase) and increased quantities of pyruvic acid (the intermediate product that thiamine helps to oxidize) in the blood Chemical and microbiological tests for the level of these substances in blood, tissues, and urine may thus serve to detect borderline deficiency of vitamin B_1.

Thiamine in Foods

Few foods relatively rich in thiamine are used in quantity in our modern diets Although almost all natural foods contain thiamine, many of them carry only minor amounts, which may be still further reduced by cooking or processing From the table of *thiamine content of foods* (p 230), it may be seen that in most fruits and vegetables, eggs, milk, and cheese it is found in amounts not exceeding 0 1 mg per 100 grams (1 part per million) In plants, it is concentrated chiefly in *seeds* (whole grains, legumes, and nuts), in animals, it is found in greatest abundance in the *organs* (liver, heart, kidneys) Pork flesh is much higher in thiamine content than other meats, but *meats* and *leafy vegetables* are moderately good sources In processed or refined foods, such as highly milled cereals, sugar, fats, and sulfured dried fruits, it is present in traces or entirely absent

Our best sources of this vitamin—*whole grains, organ meats, pork,* and *legumes*—are not used in quantity in the American dietary However, foods of more moderate thiamine content are used in sufficient amounts to provide this vitamin at a fairly safe level (perhaps an average of 1 1–1 3 mg per adult) Of this about 20–35 per cent may come from bread and cereals, 25 per cent from meats, fish, and poultry, 15 per cent from eggs and dairy products, the remainder from fruits and vegetables In low-cost diets, where grain products and potatoes furnish a higher proportion of the diet, it is especially important that bread and cereals should be of whole grain or enriched variety Such foods as oatmeal and dried legumes can be an economical source of thiamine It is significant that beriberi seldom, if ever, develops in countries where meats, dairy products, fruits and vegetables are freely used A daily intake of 1 1–1.3 mg thiamine is liberal for a calorie level of 2,000–2,500 Cal, with fat furnishing a good proportion of the calories When the caloric intake is lower (as in old people or young children) or when it is higher (as in adolescents or those who do muscular work), some extra care may be necessary to make sure of getting enough of this vitamin for health

Thiamine suffers little destruction on exposure to air at ordinary temperatures, so much less is lost in handling or storage of foods than is true for vitamin C. Losses in milling of cereal grains will be taken up

safety Thus it will be seen that some recommend as *optimum* a thiamine intake which is two to four times the amount that *others regard* as adequate.

The Food and Nutrition Board of the National Research Council has recommended (1958) a moderately liberal daily intake of vitamin B_1 for normal adults, varying according to the calorie intake recommended for the different age groups on the basis of an *assumed* degree of muscular activity, which is greater in the younger adults. The thiamine allowances, which are at a level of 0 46 to 0 55 mg. per 1000 calories irrespective of age, are as follows:

MEN			WOMEN		
Weight	*Age*	*Thiamine, mg daily*	*Weight*	*Age*	*Thiamine, mg daily*
154 lb	25	1 6	128 lb	25	1 2
" "	45	1 5	" "	45	1 1
" "	65	1 3	" "	65	1 0

The student should not be misled into assuming that age affects the thiamine requirement, except as it is usually associated with decreased *muscular activity and lowered calorie intake. Old persons need just as* much thiamine as do younger ones, *in proportion to their caloric intake*, in fact, there is evidence that tissues might be maintained in better condition in older people if their thiamine intake were more liberal Daily allowances for adults may be calculated on the basis of individual calorie requirements, allowing 0 5 mg for each 1000 Cal. up to 3000, 0 2 mg for each 1000 Cal above this level. On this basis, a man who requires 4500 Cal per day would have a daily thiamine allowance of 1 8 mg Even those who subsist on a low calorie intake should not have less than 1 mg thiamine per day.

Dietary surveys have shown that the average intake of vitamin B_1 is much nearer the minimum than the optimum level. Williams and co-workers[10] concluded that the average American diet, prior to the introduction of "enriched" bread, provided only about 0 8 milligrams thiamine per 2500 calories, which would be dangerously near the minimum requirement. Substitution of bread and cereals enriched with thiamine for those made from highly milled grains and unenriched has raised the average vitamin B_1 intake to a safer level, probably about 1.3 mg, even though the use of cereal products has declined in recent years. Of course, there are many variations from the *average* intake, some persons doubtless choose diets that provide optimum thiamine intake, while others get marginal amounts, sufficient to prevent beriberi but too low to keep their bodies *in healthy condition*

Tests have been developed by means of which it is possible to determine whether a person has been getting plenty of or much too little thiamine in the diet, i e., to measure the "*nutritional level*" of the body

[10] *Lane*, R L., Johnson, E., and Williams, R. R., J Nutr, 23, 613, 1942

Table 12. Approximate Thiamine Content of Typical Foods*

Food	Per 100 gm, raw, E.P.	Per average serving	
	Thiamine	Size of serving	Thiamine
Meats:	mg		mg.
Pork, lean	74	Pork, 3½ oz. (100 gm) roasted...	.53
Organs, heart	.58		
kidney	.37		
liver	.26	Liver, beef, 2 oz, fried	.14
Lamb, lean	.16	Lamb, lean, 3½ oz, roasted.	.14
Veal, lean	.14		
Beef, lean	08	Beef, lean, 3½ oz, broiled	.08
Oysters	15		
Chicken	08	Chicken, 3½ oz, roasted	.07
Fish	04- 10	Fish, 3½ oz, fried	06
Legumes and Nuts			
Dried, soybeans	1 07	Dried soybeans, 30 gm, ½ c cooked.	.25
other beans	67	navy beans, ½ c cooked.	.16
split peas	77	Split peas (30 gm dry), ½ c cooked..	.18
Fresh, green peas	34	Fresh green peas, 80 gm, ½ c cooked	.20 (canned .09)
lima beans	21	Fresh lima beans, 80 gm, ½ c cooked	11
Peanuts, roasted	30	Peanut butter, 30 gm, 2 tbsp ..	04
Other nuts, avg	59	Other nuts, 30 gm, 16–24 nuts..	18
Cereal Products			
Bread, whole wheat	30	Bread, whole wheat, 1 slice	07
white, enriched	.24	white, enriched, 1 slice	06
white, unenriched	05	white, unenriched, 1 slice	.01
Cereals, whole wheat dry	55	Whole wheat cereal, ¾ c cooked .	.18
oatmeal, dry	60	Oatmeal, 30 gm, dry, ¾ c cooked	.16
farina, enriched	37	Cream of wheat, enriched, ¾ c cooked	.15
farina, unenriched	06	Cream of wheat, unenriched, ¾ c cooked	02
Eggs	10	Egg, 1 whole, boiled	04
Milk, whole, fresh	04	Milk, whole, fresh, 1 pint	175
Cheese, Am cheddar	02	Cheese, Am. cheddar, 1 oz	01
Vegetables			
Potatoes	11	Potato, 1 medium (100 gm) boiled .	09
Asparagus, broccoli, cauliflower, avg.	12	100 gm svg cooked asparagus, broccoli, or cauliflower	08
Leafy, avg	10	Leafy, ½ c cooked (100 gm)	07
Others, except legumes, avg	.06	Others (exc. legumes), ½ c cooked	05
Salad greens ...	04	Salad greens, 50 gm svg, raw.	02
Fruits:			
Fresh, avg ...	04	Fruit, fresh, avg, 100 gm, raw ..	.04
Dried, avg, unsulfured	.11	Fruit, dried, avg, unsulfured, 100 gm, cooked	03
Apricots, sulfured	01	Apricots, sulfured, 100 gm cooked..	Trace

* Figures for both raw and cooked foods are from U S Dept Agric Handbook No. 8, "Composition of Foods—Raw, Processed, Prepared," 1950

are the two most concentrated sources of vitamin B_1, one level teaspoon of the yeast powder or four tablespoons of wheat germ will add about 0.45 mg. thiamine to the diet.

But the problem of raising the vitamin B_1 content of the diet is much more acute in other parts of the world than in America. Half of the world's population (chiefly in Asia) use rice as their staple food and the poorer classes often have almost nothing else to eat. Polished rice is still preferred to "brown" rice, so that the remedy has been to put back some of the thiamine removed in milling. This can be done either by parboiling the rice before milling in water to which thiamine and other nutrients have been added, or by steeping the milled rice in such an infusion.[13] Rice so treated is said to be "processed" or "converted," and is gradually coming into wider use in the Orient. Where it has been used exclusively, as in the experiment of Burch, Salcedo, and associates[14] in the province of Bataan, Philippines, the mortality from beriberi dropped quickly and the disease was virtually wiped out in about two years time. The World Health Organization is fostering such programs, but progress is necessarily slow. It is now about fifty years since beriberi was shown to be a vitamin deficiency disease and twenty years since pure thiamine became available commercially. Yet, in 1953, Williams[15] stated that "it is probable that 10 per cent of the population of rice-eating Asia could be shown to exhibit mild symptoms of the disease." In addition, many people (in Africa, Central and South America, and the southern part of the United States) use corn as their chief grain food and, if it is highly milled and degerminated, there will be a deficiency of vitamin B_1, as well as of other nutrients, in their diets. Clearly the problem of raising the thiamine content of the diet is still of pressing importance in many parts of the world.

RIBOFLAVIN (VITAMIN B_2)

Discovery

In the course of years of experimenting with the growth-promoting factor called "water-soluble B," it became evident that there must be at least two vitamins associated in yeast, liver, and the outer coats of grains. Severe heating (at 120° C. in an autoclave for several hours) completely destroyed the anti-beriberi vitamin (B_1, or thiamine) in yeast, but there remained another vitamin fraction which showed growth-promoting potency. Although this heat-stable fraction is now known to consist of several vitamins, the one first discovered and studied was called *vitamin G or B_2.*

[13] Salcedo, J., Jr., *et al.*, "Artificial Enrichment of White Rice as a Solution to Endemic Beriberi," J. Nutr., 42, 501, 1950.

[14] Burch, Salcedo *et al.*, J. Nutr., 42, 9, 1950, ibid., 46, 239, 1952.

[15] Williams, R. R., "The World Beriberi Problem Today," J. Clin. Nutr., 1, 513, 1953.

the various constituents in the cereal grains. Each kernel consists of (1) the outer husks or bran, (2) the brownish outer part of the kernel or aleurone layer, (3) the inner, main portion or endosperm, and (4) the small germ at one end of the kernel. Most of the vitamins and minerals, and much of the protein, are in the aleurone layer and germ, the inner part of the kernel consists chiefly of starch, with some protein. Usually the harsh bran and the germ are removed in milling, the former to promote digestibility and the latter to improve the keeping qualities of the product. If, in addition, most of the aleurone layer is removed, as in high degree of milling, very little of the original vitamin and mineral content of the grain will be left. Thus, about seven-eighths of the thiamine and a large part of the protein, iron, and other B complex vitamins (riboflavin and niacin) are lost in the process of making white flour, and much the same is true in the high milling of rice. The by-products (containing the germ and outer coats of the grain) are used for animal feed.

To meet possible deficiencies in the diet, the United States government launched (in 1940) a program to "enrich" white bread by the addition of thiamine, along with two other B vitamins and iron. Soon after, different manufacturers of breakfast cereals began to "restore" their highly milled products by addition of the above nutrients up to about the level found in whole grains.[11] A good many states (and Canada) now have laws that all white bread sold must be of the "enriched" kind. Even with 4 per cent milk solids in the white enriched bread, it is still not quite up to the content of whole wheat bread in protein, calcium, iron, thiamine and niacin, while the whole grain breads contain other B complex vitamins not added in the enrichment of white flour. For these reasons, many nutritionists feel that whole grain breads and cereals are still preferable, but the enrichment of white bread (consumed in far the largest amounts) has done much to improve the diet, especially as to thiamine. This is particularly important in diets where a high proportion of the calories come from carbohydrate, less important when a considerable amount of energy is furnished by fats, which do not require thiamine for their metabolism.

Other means, beside the official enrichment of white flour, may be used to increase the amount of thiamine (and other nutritive factors) carried by cereal foods. Peanut butter, soy grits, nuts, and dried skim milk are all excellent sources of thiamine, any of these may be incorporated in home-baked bread or cookies. Baking companies sometimes improve the nutritive quality of bread by adding dried skim milk, dried brewer's yeast, or wheat germ, and homemakers may add them to rolls, muffins, or breakfast cereals. Wheat germ and dried brewer's yeast[12]

[11] For enrichment standards, see National Research Council Bull. No. 110, 1945.

[12] Brewer's yeast is 8–10 times richer in vitamin B_1 than is baker's yeast. It should

are the two most concentrated sources of vitamin B_1, one level teaspoon of the yeast powder or four tablespoons of wheat germ will add about 0 45 mg thiamine to the diet.

But the problem of raising the vitamin B_1 content of the diet is much more acute in other parts of the world than in America Half of the world's population (chiefly in Asia) use rice as their staple food and the poorer classes often have almost nothing else to eat Polished rice is still preferred to "brown" rice, so that the remedy has been to put back some of the thiamine removed in milling. This can be done either by parboiling the rice before milling in water to which thiamine and other nutrients have been added, or by steeping the milled rice in such an infusion [13] Rice so treated is said to be "processed" or "converted," and is gradually coming into wider use in the Orient Where it has been used exclusively, as in the experiment of Burch, Salcedo, and associates[14] in the province of Bataan, Philippines, the mortality from beriberi dropped quickly and the disease was virtually wiped out in about two years time The World Health Organization is fostering such programs, but progress is necessarily slow It is now about fifty years since beriberi was shown to be a vitamin deficiency disease and twenty years since pure thiamine became available commercially Yet, in 1953, Williams[15] stated that "it is probable that 10 per cent of the population of rice-eating Asia could be shown to exhibit mild symptoms of the disease " In addition, many people (in Africa, Central and South America, and the southern part of the United States) use corn as their chief grain food and, if it is highly milled and degerminated, there will be a deficiency of vitamin B_1, as well as of other nutrients, in their diets Clearly the problem of raising the thiamine content of the diet is still of pressing importance in many parts of the world

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[13] Salcedo, J. [illegible] Solution to En-

[illegible] Nutr, 1, 513,

Chemical Identification and Properties

Vitamin B_2 was isolated in pure crystalline form from yeast, liver, egg white, and milk (whey), and proved to be identical chemically from whichever of these sources it was obtained. In due time its chemical structure was determined, and it was made in the laboratory. This substance was named *riboflavin*.

Riboflavin received its name because it is a compound of ribose (a five-carbon sugar) with a complex colored substance, called flavin The vitamin is an orange-yellow solid, which imparts a greenish-yellow fluorescence to solutions It is *soluble in water* and stable to heating in neutral or acid solutions, but may be destroyed by heating in alkaline solution or by exposure to light Although riboflavin (B_2) usually occurs along with thiamine (B_1) in foods, certain foods are especially good sources of one of these vitamins and comparatively poor in the other. Egg white is the only food in which vitamin B_2 is known to occur with only traces of vitamin B_1.

Riboflavin (free or in combined forms) is very widely distributed in both plant and animal tissues It is formed by all higher plants, chiefly in the green leaves, and the younger parts of the plant contain more than older parts, seeds are rather low in riboflavin, except when sprouting Most microorganisms also synthesize this vitamin, and bacteria in the intestinal tract may be a considerable but variable source of it for animals Aside from this undependable source, animals must get riboflavin in their food

Effects of Riboflavin Deficiency

The vitamin potency of riboflavin was discovered by its effect on *growth*. Experimental animals which receive little or no riboflavin show stunted growth, and when fed graded amounts of this vitamin they respond with corresponding increases in growth rate. Sherman and Ellis[16] have also shown that animals fed more liberal quantities have better health and vigor, greater ability to bear and suckle offspring, delayed senility, and longer life. When the diets of higher riboflavin content were continued for several generations of experimental animals, the benefits to general vitality were more marked in the later generations and at levels of vitamin intake up to more than twice the amount of vitamin B_2 required to prevent deficiency symptoms That riboflavin is one of the factors essential for successful *reproduction* was also demonstrated by Warkany and Schraffenberger,[17] who found that rats on diets deficient in this vitamin produced young with abnormal skeletons and other defects

[16] Sherman, H. C., and Ellis, L. N., J Biol Chem, 104, 91, 1934; Proc. Nat'l Acad Sci, 25, 420, 1939, J Nutr, 25, 153, 1943

[17] J Nutr, 27, 477, 1944

This vitamin promotes general health at all ages, because it is the active constituent of several enzymes or coenzymes that are essential to oxidation processes in the various body tissues, it seems to be essential for the health of tissues of ectodermal origin, such as the skin, eyes, and nerves. In experimental animals long-continued lack of riboflavin leads to *sore mouth and nose*, falling hair and *scaly skin*, *eye symptoms* varying in severity from an inflamed condition of the cornea to its complete opacity in cataract, *digestive disturbances*, *nervous lesions* (severe cases show paralysis of hind legs), poor utilization of food as shown by loss of weight, increasing weakness, and death In man, lack of vitamin B_2 produces less noticeable symptoms Sebrell,[18] who first produced experimental deficiency of this vitamin in human beings, reported as characteristic symptoms reddened, denuded areas on the lips, with cracks at the angles of the mouth Later investigations[19] have shown that eye symptoms also occur in man as early evidence of vitamin B_2 lack, these include low-grade inflammation of the conjunctiva or cornea and a kind of "twilight blindness" somewhat similar to that produced by lack of vitamin A Others[20] have further defined eye lesions characteristic of riboflavin deficiency and emphasized that these are not specific unless they clear up on giving additional amounts of that substance Other in-

A B

Figure 80 Two views of the same rat A, after cataract developed in the left

Health)

[18] Sebrell, W H, and Butler, R E., U S Pub Health Reports, 53, 2282, and 54, 2121, 1939

[19] Kimball, M S, and Gordon, E S, J Biol Chem, 128, lii, 1939, Sydenstricker, Sebrell, *et al*, J A M A, 114, 2437, 1940, McCreary, Nichols, and Tisdall, J A M A, 126, 595, 1944

[20] Mann, I, Am J Ophth, 28, 243, 1945, Spies, T D, *et al*, J Lab & Clin. Med., 30, 751, 1945.

A B

Figure 81 Patient before and after treatment for riboflavin deficiency A, showing excrescences on the forehead, nose, cheeks, lips, and chin, and in the folds around nose and mouth, B, after treatment with riboflavin, 15 mg first two days, 10 mg for next two days, and 5 mg daily for one week (Courtesy of Dr. Bernard Read and Dr H C Hou, Shanghai, and Messrs Wm Heinemann, Ltd, London)

vestigators[21] have shown that various symptoms of general debility in man (such as are often seen in pellagra) may be associated with a deficient intake of this vitamin. In both man and animals, most of these symptoms disappear promptly when synthetic riboflavin is given.

Riboflavin in the Body

Riboflavin exists in foods in the free form and also in combination with protein and/or phosphoric acid The form in which it occurs in food seems to have little effect on its absorption and nutritive value One theory is that free riboflavin must be combined with phosphoric acid in the intestine before it is absorbed, and in this form it aids the absorption of sugars and amino acids It is claimed that liberal riboflavin in the diet is accompanied by more efficient utilization of protein intake, that high intakes of protein are not well tolerated by riboflavin-deficient animals, and that adequate amounts of this vitamin are important for rebuilding body protein after periods when it has been depleted by extra stresses Whether or not vitamin B_2 plays any specific role in protein utilization, it does seem to promote better utilization of the diet as a whole.

[21] Spies, T. D, *et al*, Am J M Sc, 200, 697, 1940, Rosenblum, L A, and Jolliffe, N, J.A M A, 117, 2245, 1941

The chief function of this vitamin, however, is the role it plays in *oxidation-reduction reactions in the tissues.* Riboflavin is contained in a number of different *enzymes* whose function is to take on hydrogen and pass it on to another substance in the long chain of oxidation-reductions by which hydrogen is finally combined with oxygen to form water In this way, riboflavin-containing enzymes assist in the metabolism of carbohydrate, of amino acids, and perhaps also of fats These enzymes are formed in tissue cells and carried in the blood Probably because riboflavin compounds, while functioning as enzymes, are built into muscle and glandular tissues (especially the liver and kidneys), the body is depleted of riboflavin more slowly than it is of thiamine

Since riboflavin is essential to numerous chemical changes in tissues, it is natural that deprivation of this vitamin causes damage to many different types of tissue, and that liberal intakes of it promote the welfare of the body as a whole Sherman, on the basis of his experiments with higher levels of intake in rats, especially stresses the relation of this vitamin to health "And this is true both for health as freedom from disease and for the upbuilding and maintenance of that higher health which is rightly regarded as a positive quality of life"[22]

Attempts to follow the distribution of vitamin B_2 in the body have met with less success than was the case with vitamins B_1 and C, due partly to difficulties in the methods for its determination, partly to the fact that it is bound so closely in the tissues. We know that riboflavin is found in almost all tissues (especially in muscles and glands) and is excreted both in the feces and in the urine The quantity of this substance

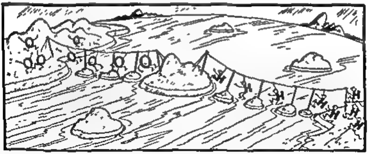

Figure 82 Diagram to illustrate how enzymes or co-enzymes, which contain

London)

[22] Sherman, H C, and Lanford, C. S, ESSENTIALS OF NUTRITION, p 242 Macmillan, 4th ed, 1957

in the urine reflects only the level of day-to-day intake, and is not a reliable measure of the stores of it in the body. However, in cases of long-standing deficiency, urinary excretion is abnormally low and more of a test dose is retained in the body (and less is excreted in the urine) than in persons whose intake has been adequate for body needs. Several investigators[23] have reported that vitamin B_2 deficiency is fairly common in the United States among adults, as well as among infants and children, a high incidence of this deficiency has also been reported from certain regions in China, India, and Africa.

Interrelations between Different B-Complex Vitamins

Since thiamine, riboflavin, and niacin all form part of enzymes or co-enzymes that help catalyze oxidation-reduction processes in body tissues, it seems reasonable to suppose that there may be some overlapping of their functions We do not know yet to what extent this is true, i e., in what cases each may be indispensable for a particular chemical reaction, or whether in other cases their functions may be parallel so that one may partially take the place of another which is in short supply. Extensive research is in progress to attempt to answer these questions but, for the most part, it is of too complicated a nature to report here, a few examples may be cited as indicative of probable interrelations between vitamins of the B group

Animals that have been fed a high level of riboflavin were found to suffer less damage as the result of subsequent deprivation of thiamine Although folic acid and vitamin B_{12} are the chief vitamins that promote regeneration of red blood cells, other B vitamins seem to assist in some way, deficiency of several of the B vitamins has a tendency to induce anemia, and administration of riboflavin led to increased production of hemoglobin in dogs rendered anemic by bleeding. Likewise, the symptoms seen in pellagra are often due to the combined lack of several B-complex vitamins, not to simple deficiency of niacin.

For the elementary student, it is sufficient to remember that such interrelationships probably exist and hence that the diet should supply a well balanced mixture of all the vitamins of the B group, such as is provided by foods in their natural state Also, if large doses of one or more vitamins of this group are prescribed for therapeutic purposes, it is wise to take B-complex capsules at the same time, so that there will not be a high intake of certain factors and a current deficiency of others

Requirements and Standard Allowances

Authorities differ on the quantities of B_2 which they deem essential to health Although people may get along on lower levels of B_2 intake

[23] Papers cited in footnote 19, page 235, also Sydenstricker, V P, *et al.*, Am J Pub Health, 31, 344, 1941, and Kruse, H D, *et al*, Nat Research Council, Bull No 109, 1943.

without showing any striking symptoms of deficiency, most nutritionists believe that more liberal allowances of this vitamin are conducive to better health. For adults, the *minimum* of 1 milligram of riboflavin daily is required, but Sebrell[24] has estimated that as much as 3 milligrams daily may be needed for health. The amount required may vary somewhat according to age, body weight, caloric intake, or amount of protein in the diet. The U. S. Food and Nutrition Board recommends 0.025 mg. for each gram of protein allowance, the Canadian Council of Nutrition 0.5 mg. per 1000 Cal. of food consumed. *Children* need liberal allowances of riboflavin to provide for maximum growth and development of healthy tissues. The need for this vitamin is also high in *pregnancy* and *lactation*.

Recommended *daily allowances*[25] for vitamin B_2 strike a median between the amounts actually required to avoid nutritional disaster and those advised by some as "optimal" for health, as follows:

	Riboflavin, mg
Men, average weight	1.8
Women, average weight	1.5
Girls, 13 to 20 years	1.9–2.0
Boys, 13 to 20 years	2.1–2.5
Pregnant and lactating women	2.0–2.5

Riboflavin in Foods

It will be seen from Table 13 that ***liver, cheese, eggs, leafy vegetables, lean meats, legumes,*** and ***milk*** are the foods that rank highest in their content of vitamin B_2. Both vitamins B_1 and B_2 are almost universally distributed in foods, i.e., only such foods as pure sugars and fats are entirely lacking in them. While the B vitamins occur together in foods, B_2 is more plentifully supplied in most foods than B_1, and this is notably true of organ meats, leafy vegetables, eggs, and milk. Milk carries about four times as much riboflavin (B_2) as thiamine (B_1). On the other hand, the whole-grain cereals, which are one of the richest sources of vitamin B_1, have only a moderate content of B_2, even when enriched with riboflavin to the level of whole grains, bread and cereals still contribute only about one-seventh of the B_2 in the average American diet. Legumes, nuts, and muscle meats are good sources of both B_1 and B_2. Pork, which has five to seven times the thiamine content of other meats, does not differ from other meats in riboflavin content. Eggs are richer in this vitamin than are muscle meats. Vegetables, other than leafy ones and legumes, and fruits contribute lesser but appreciable amounts of riboflavin in the diet.

Fortunately, riboflavin is sufficiently stable on heating so that little of it is destroyed in ordinary cooking processes, although some may be

[24] Sebrell, W. H., *et al.*, U. S. Pub. Health Reports, 56, 510, 1941.
[25] Recommended by Food and Nutrition Board, National Research Council, 1958.

Table 13. Approximate Riboflavin Content of Typical Foods

Food	Per 100 gm., raw, E. P.	Per Average Serving	
	Riboflavin	*Size of Serving*	*Riboflavin*
	mg.		mg.
Liver, beef	3 33	2 slices, fried liver (74 gm.)	2.56
Cheese, Am cheddar	42	1 oz cheese	.12
Eggs, whole	29	1 egg, boiled	.13
Leafy vegetables, avg	27	½ c. leafy veg, ck. (100 gm).	.24
Meats, lean muscle, avg	.20	3½ oz cooked lean meat	.17
Milk, whole, fresh	17	1 pint milk	.84
dried, skim	1 96	1 tbsp. dried skim milk	.15
Legumes, dried	.25	½ c. baked beans, canned	.045
fresh, green peas	.16	½ c. green peas, fresh, ck.	.11
fresh, lima beans	.11	½ c. green peas, canned, solids	.05
Nuts, avg (mixed nuts)	13	1 oz, 16–24 nuts	.04
Peanut butter	.13	2 tbsp. peanut butter	.04
Whole grains	145	⅔ c. whole grain cereal, ck.	.03
Bread, enriched white	15	1 slice enriched white bread	.04
whole wheat	13	1 slice whole wheat bread	.03
Dried fruits, avg	13	4–5 med prunes, ck	.045
		Apricots, dried, ck., 4 halves	.04
Vegetables (other than leafy and legumes), avg	.07	1 avg. svg. vegetable (100 gm.) ck	.06
Fresh fruits, avg	.04	1 avg svg fresh fruit (100 gm)	.04

lost by solution in water in which foods are cooked or canned Average losses of riboflavin in cooking are 15–20 per cent in meats, 10–20 per cent in vegetables, and 10 per cent in baking bread

Because of the importance of milk as a dietary source of this vitamin, the possible destruction of riboflavin on exposure of milk to light has been emphasized Exposure to ordinary daylight may cause considerable losses,[26] and milk in a glass bottle left standing on the doorstep in direct sunlight may lose 50–70 per cent of its riboflavin potency in two hours time [27] The use of paper cartons cuts down losses by exposure to sunlight or display lighting in foodstores, but even so it is best to keep milk as much as possible in a cool, dark place, such as the refrigerator *Only minor losses of riboflavin occur in pasteurization of milk* or the brief exposure to ultraviolet light sometimes used to increase its vitamin D content [28]

[26] Williams, R J, and Cheldelin, V H, Science, 96, 22, 1942.
[27] Ziegler, J A, J Am Chem Soc, 66, 1039, 1944
[28] Ziegler and Keevil, J Biol Chem, 155, 605, 1944

Foods Required To Furnish Standard Allowance

A pint of milk will provide almost half the daily allowance of vitamin B_2; children who take a quart of milk each day will be fairly certain of getting plenty of this vitamin. The following group of foods, as basis of the daily diet, will provide approximately 1.7 ***milligrams of riboflavin***:

Milk, 1 pint	1 serving leafy vegetable
Meat, 3½ oz	2 servings other vegetables
1 egg	2 servings fruit
4 slices whole wheat bread	

It might seem that there should be no difficulty in getting enough riboflavin in the diet, but there is doubt whether many diets furnish the ***optimum*** amounts. Many persons do not use milk, eggs, leafy vegetables, and legumes in liberal quantities. It is of interest that Sydenstricker and co-workers[29] found several persons with symptoms of riboflavin deficiency among the staff of a Southern hospital, who were supplied with a satisfactory diet but simply neglected to take the milk, eggs and green vegetables provided. It is probable that many people in low-income groups do not get enough of these riboflavin-bearing foods (plus meats) and hence have too low an intake of this vitamin for health. Without a quart of milk daily it is difficult to plan diets that would provide the high levels of 2.0 to 2.5 milligrams of riboflavin which are recommended for pregnant or lactating women, and for teen-age boys and girls.

NIACIN (NICOTINIC ACID)

Discovery

Not until 1937–1938 was this substance established as a member of the group of B vitamins and identified as the long-sought ***"pellagra-preventing factor."*** Goldberger had demonstrated, nearly twenty years earlier, that pellagra was directly due to faulty diet, and later that this disease could be prevented or its symptoms relieved by giving liver, yeast, lean meats, or other foods rich in B-complex vitamins.[30] Pellagra had occurred in certain parts of Europe for over 200 years, being especially prevalent in areas where corn formed a large part of the diet; one of its most typical symptoms is a reddish skin rash which later makes the skin dark and rough, from which it took the name of pellagra, an Italian word meaning "rough skin." Although a few early physicians were convinced that it was caused by dietary deficiencies, the theory was advanced that it might be due to some toxic substance present in corn, or developed in corn on spoilage. About 1907, the disease became prevalent in the southern parts of the United States, and cases increased in number so

[29] Sydenstricker, V. P., Sebrell, W. H., Cleckley, H. M., and Kruse, H. D., J.A.M.A., 114, 2437, 1940.

[30] Goldberger, J., et al., U. S. Pub. Health Reports, 33, 2038, 1918, and four articles in 35, 1920.

Figure 83 Pellagra in a child, showing typical red rash on face and hands. (Courtesy of Dr John A McIntosh)

rapidly that in 1915 over 10,000 persons died of it and in 1917–1918 there were 200,000 cases of it in this country.

This was of great concern to the United States Public Health Service, which instituted special studies of the disease, at first opinion was divided as to whether it was due to poor sanitation or diet but later, when Goldberger had induced the disease solely by feeding a "poor" diet to volunteer convicts and had prevented its incidence in various institutions by improvement of the diet, it was established as a dietary deficiency disease Although Goldberger[31] proved that the preventive factor was a heat-stable substance present in yeast after thiamine had been destroyed by autoclaving, the exact nature of the substance remained a mystery until Elvehjem showed that black tongue, an analogous disease in dogs, could be cured by giving *nicotinic acid*.[32] Administration of this substance or a related compound, *nicotinic acid amide*, was soon shown by several investigators[33] to cure the most striking and characteristic symptoms of pellagra in humans Even before these discoveries, preventive dietary measures had been instituted in the southern states, which resulted in marked decrease in pellagra incidence until by 1945 acute cases were rarely seen. The disease continues to be encountered frequently in other areas of the world where corn (or other highly milled cereal) constitutes the major item of food.

Properties of Niacin

Both nicotinic acid and its amide have been found to be normal constituents of living cells and to be present in foods, especially in liver, muscle meats, wheat germ, legumes, and leafy vegetables The simpler names, *niacin* and *niacinamide*, have been adopted by the American Medical Association and the Institute of Nutrition, with the idea of

[31] Goldberger, J, *et al*, U S Pub Health Reports, 41, 297, 1926

[32] Elvehjem, C A, *et al*, J Am Chem Soc., 59, 1767, 1937, J. Biol. Chem, 123, 137, 1938

[33] Fouts, Helmer, Lepkowsky, and Jukes, Proc Soc Exp Biol. & Med, 37, 405, 1937; Smith, Ruffin, and Smith, J A M.A, 109, 2054, 1937, Spies, T D, *et al*, J.A.M A, 110, 622 and 111, 584, 1938, also Ann Int Med, 12, 1630, 1939.

avoiding any possible implication that these normal nutrients are related in nature to nicotine, the alkaloid in tobacco. Both have been obtained in pure crystalline form from foods and tissues, and both have been synthesized in the laboratory. They are fairly simple organic substances—niacin is a nitrogen-containing acid and niacinamide is a basic salt of this acid. They may be present in foods or tissues in free or combined forms. The amide form is preferred for therapeutic doses, since it does not cause the unpleasant skin reactions (feeling of heat, flushing, or even a red rash) and dizziness often associated with administration of the acid. In common nutritional parlance the term niacin is used to designate this *nutrient factor*, including both the acid and amide in free or combined forms.

Niacin is soluble in water but is an unusually stable compound, since it withstands both heating and oxidation, and is unaffected by acids or alkalis. Hence, there is little loss of this vitamin in cooking procedures except as some of it may be lost in solution in discarded cooking water.

Symptoms Due to Lack of Niacin

The tissues that show damage as a result of niacin deficiency are chiefly the skin, the gastrointestinal tract, and the nervous tissues.

The most striking and characteristic *symptoms of pellagra* are a reddish skin rash (especially on face, hands, and feet when exposed to light) which later makes the skin dark and rough, sore mouth and tongue, inflamed membranes in the digestive tract, with bloody diarrhea in the later stages, and also, in advanced cases, distressing nervous and mental disturbances. Physicians sometimes refer to pellagra symptoms as "the three D's—dermatitis, diarrhea, and depression or dementia," and consider that when either the digestive or the nervous disturbances occur along with the characteristic skin lesions a diagnosis of pellagra is justified.

A B

Figure 84. Cure of pellagrous lesions on hands of an adult by diet rich in B vitamins, especially niacin. *A*, hands of pellagra patient; *B*, same patient after two weeks of corrective diet. (Spies, REHABILITATION THROUGH BETTER NUTRITION.)

Less acute symptoms of niacin deficiency may be hard to recognize. Kruse[34] has described changes in the tongue which he believes are among the earliest signs of niacin lack and may be used to detect it. *Latent* or mild pellagra has been reported in infants and children,[35] in whom the usual pellagra symptoms were lacking but weakness and failure to grow properly responded favorably to treatment with niacinamide. Hence we see that this vitamin is necessary for *growth* and for *health of tissues*, and it has also been shown to promote appetite, proper functioning of the digestive tract, and good utilization of foodstuffs in the body.

The Pellagra Problem

The wide occurrence (and subsequent conquest) of pellagra in the southern United States affords *an interesting example of the relation of* nutritional welfare to economic conditions, and also of a dietary deficiency disease that is not due to simple deficiency of *one* vitamin. The South was a "one crop" region, depending almost entirely on cultivation of cotton and its manufacture into cloth. The cash income of ordinary people was low, so that they ate the cheapest foods obtainable and became habituated to a "poor" type of diet, many poor share croppers and mill hands lived almost exclusively on corn meal and grits, soda biscuits, corn sirup or molasses, and fatty salt pork—a diet that is deficient both as to quality and quantity of protein and in content of several vitamins and minerals When pellagra developed on such diets, although most of the symptoms were due to lack of niacin, the disease was complicated by lack of other B-complex vitamins, especially thiamine and riboflavin Not only the corn products but any flour and rice used were degerminated and highly milled, most of the natural content of thiamine, riboflavin, and niacin was removed with the germ and outer coats of the grains. There was almost no lean meat, milk, or eggs to contribute high quality protein and B vitamins Riboflavin deficiency is so often associated with niacin deficiency on such diets as to be said to have a bearing on the occurrence and persistence of pellagra. In fact, pellagra is now considered to be a *complex* dietary deficiency, many of whose symptoms are due to niacin deficiency but whose complete cure requires all-round improvement of the diet, especially of its protein content and intake of all the B-complex vitamins

Hence, the campaign to stamp out pellagra centered on the possibilities of introducing into the diet certain foods found to be missing where the disease occurred and experimentally established as effective in preventing the disease Lean meats, milk, eggs, canned salmon, peanuts, peas, and leafy vegetables were shown to be good foods to add to the

[34] Kruse, H D, Milbank Memorial Fund Quart, 20, 262, 1942

[35] Spies, T. D., et al, J.A.M.A., 113, 1481, 1939

diet for preventing pellagra[36] At the same time, Wheeler and Sebrell[37] commented, "In looking for cases of pellagra, the home surrounded by evidence of a good garden, or a cow or two, a few pigs and some poultry may as well be passed up, for the chances are less than one in a thousand that pellagra will be found On the other hand, the home surrounded only by last year's cotton patch will always bear watching" Because many families did not have money to buy the needed foods, the campaign was centered on urging them to make home gardens, and to keep a cow and some chickens In some areas, the Red Cross would lend the family a cow until the health, and with it the earning power, of the people improved sufficiently to enable them to buy the animal While the educational campaign went on, public health authorities in some states supplied free dried brewer's yeast, which has a higher content of niacin and other B vitamins than any food The result of health education was demonstrated by a dietary survey made in two adjacent communities in the Kentucky mountains,[38] one of which had a high incidence of pellagra while the other had almost none, corn products were eaten in about the same amounts in both districts, but the people in the one which had been freed from pellagra had been influenced by the Frontier Nursing Service to understand the importance of certain foods for health, so that they had planted gardens and were keeping cows and chickens (which was not true in the other district)

This campaign to educate the people in change of food habits and increase income levels to make possible the purchase of needed foods was gradually successful, DeKleine[39] called attention to the decrease in mortality from pellagra in southern states from 22 4 to 5 1 per 100,000 between 1929 and 1940 Since the discovery of the benefits of treatment with niacin, the public institutions are no longer crowded with pitiful and hopeless cases of this disease Although the number of acute cases and of deaths from this disease is now low, much remains to be done toward permanent improvement of the nutritive qualities of the diet, in order to avoid low-grade niacin deficiency and to make the diet otherwise adequate in all respects to promote health

Niacin in the Body

The chief function of niacin in the body is to form the active portion of *coenzymes that play an essential role in tissue oxidations*, and it thus promotes the health of tissue cells Niacinamide, in both free and combined form, is carried in the blood and found in all tissues, but most richly in liver, kidney, heart, brain, and muscles It is built into two

[36] Sandels and Grady, Arch Int Med, 50, 362, 1932, Stiebeling and Munsell, U S Dept Agric, Tech Bull 333, 1932, Sebrell, W H, U S Pub Health Reports, 49, 754, 1934

[37] Wheeler, G. A, and Sebrell, W H, J.A.M.A, 99, 95, 1932

[38] Kooser, J H, and Blankenhorn, M A, J.A.M.A, 116, 912, 1941.

[39] DeKleine, W, Southern Med J, 35, 992, 1942

coenzymes (coenzymes I and II), which by virtue of their ability to alternately *take on* or *give off* hydrogen, act as "hydrogen carriers" (in conjunction with riboflavin-containing enzymes) in passing along this element from fuel materials (chiefly carbohydrate) to its eventual union with oxygen Lack of niacin to form these enzymes in sufficient quantities will handicap vital chemical processes and may result in injury to tissues throughout the body

[illegible] niacin in the body (chiefly in the liver), [illegible] the urine. Chemical tests on blood and [illegible] ve not been very successful, though pellagra patients have [illegible] to excrete less niacin derivatives in the urine than do normal persons. Chemical [illegible] assaying niacin and its amide in tissues or food materials are [illegible] these substances from the com- [illegible] biological assays are more [illegible]

Study of the metabolism of niacin and the [illegible] be furnished in the diet is complicated by two facts—(1) it can be synthesized by bacteria in the intestinal flora, and (2) it can be made from the amino acid tryptophan, either in the tissues or by microorganisms in the intestine, probably the former We know that many bacteria can synthesize this and other B vitamins. In human experiments, the feces are frequently found to contain more niacin (or its compounds) than was present in the food and there is evidence that this vitamin can be synthesized in the human gut[40], since some diets are more favorable for this synthesis than others, the variability of the amounts synthesized may sometimes determine whether or not pellagra occurs when the diet contains borderline quantities of niacin

It is now well established that tryptophan, supplied by proteins in the diet, has a sparing action upon the amount of niacin needed in the diet, because it acts as a precursor substance from which niacin can be formed in the body Krehl and associates[41] demonstrated the transformation of tryptophan to niacin in the rat, and several other species of animals, including man, can also bring about this chemical change Experiments[42] have shown that rats, which ordinarily get all the niacin they need from intestinal synthesis, failed to grow normally, or showed other signs of niacin lack, on diets containing large amounts of corn, symptoms of niacin deficiency were prevented on the same diet if either niacin or tryptophan was given in fairly small amounts Thus we have an explanation of why pellagra occurs so often among peoples who subsist on large amounts of corn. Corn not only supplies little niacin but its

[40] Najjar, V. A, *et al*, *Proc Soc Exp Biol & Med*, 61, 371, 1946, Elvehjem, C. A, *J. Am Dietet Assoc.*, 22, 959, 1946

[41] Krehl, Elvehjem, *et al*, *J Biol Chem*, 158, 13, 1944, and 164, 551, 1946

[42] Wintrobe, M M., *et al*, *J Nutr*, 30, 395, 1945, Krehl, Elvehjem, *et al*, *J. Nutr*, 31, 85, 1946

Table 14 Approximate Niacin Content of Typical Foods*
(Per 100 Grams of Raw Food)

Food	*Niacin*	*Food*	*Niacin*
	mg		*mg.*
Liver, calf.	16 1	Dried fruits (exc raisins),	
Peanuts (peanut butter). . ..	16 2	avg	2 0
Tuna fish, canned, solids	12 8	Nuts (not peanuts), avg	2 2
Heart, beef	7 8	Peas, dried.	3 1
Salmon, canned, red	7 3	Beans, dried .	2 2
Meats, lean muscle, avg .	4 6	Green peas, fresh	2.7
Whole wheat... .	4 4	Lima beans, fresh.	1 4
Bread, whole wheat	3 [illegible]	Corn, sweet, fresh.	1 7
enriched white... .	2 2	Broccoli... . ..	1.1
Corn meal, whole, dry.	2 0	Leafy vegetables, avg	7
degerminated .	1 0	Other vegetables, avg	.5
degerminated, en-		Fresh fruits, avg .	.3
riched . .	3 5	Cheeses	.1–.2
Rice, white.. ..	1 6	Eggs, whole, fresh . .	.1
Oatmeal, dry.	1 0	Milk, whole, fresh	.1

* Figures from U. S Dept Agric. Handbook No 8, "Composition of Foods—Raw, Processed, Prepared," 1950

protein has an unusually low content of tryptophan, thus the diet is low *both in niacin and in the precursor* from which it can be formed in the body The relatively low content of both niacin and tryptophan in corn, as compared to that in wheat, is shown by the figures below

	Niacin	*Tryptophan*
Whole wheat per 100 gm	4 3 mg	168 mg
Whole corn, per 100 gm	2 0 mg	55 mg

The fact that the body can form niacin from tryptophan also explains why some foods have far greater pellagra-preventing potency than would be expected from their actual content of niacin Such foods are milk and eggs, which are low in niacin but carry *proteins that are* high in the amino acid tryptophan, thus furnishing the body with protection from pellagra by enabling it to build niacin within the tissues.

Niacin in Foods

Since niacin can be formed in the body if the proper precursors are furnished, it should be clear that the amount of preformed niacin in the foods that comprise the diet is not necessarily a measure of the total quantity of this vitamin available to the body For foods such as milk, cheese, and eggs, their pellagra-preventing action is greater than would be expected from assays as to their niacin content. For comparisons between meats or cereal products, microbiological assay or determination by chemical methods seems to give closer agreement between niacin content and pellagra-preventive powers The values for niacin content of

foods, as given in government tables, are of interest in indicating what types of foods are relatively rich in this vitamin so that, with the caution that niacin "values" and niacin "contents" of foods are not always parallel, such figures are given in Table 14. Since there is very little destruction of niacin in ordinary cooking methods, figures for cooked foods are omitted.

It should be noted that most of the foods that are good sources of thiamine and riboflavin are also high in niacin content, namely liver, lean meats, whole grains, nuts, and legumes However, eggs, milk, and cheese are relatively low in niacin, while leafy vegetables are not much higher than other vegetables *As with vitamins B_1 and B_2, foods that are not rich in this vitamin may yet furnish considerable amounts of it if they are eaten in quantity*

Under the "enrichment" program, niacin has been added to staple foods made from highly milled cereals The higher niacin content of enriched white bread and enriched degerminated corn meal should be noted in Table 14. Processed rice also contains more niacin (as well as more thiamine and riboflavin) than ordinary white rice.

Niacin is present in most foods in much larger amounts than is thiamine or riboflavin For instance, lean muscle meats carry about 30 times as much niacin as thiamine (except for pork) and over 20 times as much niacin as riboflavin.

Requirement and Recommended Allowance

It should be evident from the foregoing discussion that the actual *requirement* for niacin will vary with the nature of the diet (whether the dietary protein furnishes much or little tryptophan). Aykroyd[43] found that 5 mg daily seems to be adequate for rice-eating adults, whereas corn-eaters may develop pellagra on somewhat higher intakes. Frazier and Friedman[44] concluded that people living on a "marginal" diet, which contained considerable corn products, would require a minimum intake of 7.5 mg niacin daily in order to prevent pellagra As the result of experiments with women on "marginal" diets in which either corn or wheat was the chief staple, Goldsmith and coworkers[45] decided that the minimal requirement of adults on diets that provide tryptophan scantily would be about 7 mg niacin per day. However, if the niacin expected to be formed from the tryptophan in the diet is added to that preformed in the food, it would seem that the minimum requirement for prevention of pellagra is about 9 mg. daily

The *recommended allowances* should, of course, be at least 50 per cent higher than the minimum requirements, in order to provide a safe margin for health. It is evident that the total amount available to the

[43] Aykroyd, W. R., and Swaminathan, M., Indian J M Research, 27, 667, 1940
[44] Frazier, E. I., and Friedman, T E., Quart. Bull Northwestern Univ Med School, 20, 24, 1946
[45] Goldsmith, G A., Sarett, H P., Register, U. D., and Gibbens, J., J Clin Invest., 31, 533, 1952

body will include not only the preformed niacin in the food but also that which is formed in the body from tryptophan obtained from digested food proteins. It became of great interest, therefore, to determine to what extent tryptophan can be counted on to be converted into niacin in the body Two recent papers[46] reviewed the evidence and concluded that, as an average figure, about 1 mg of niacin could be expected to be formed for each 60 mg. of tryptophan ingested In their 1958 revised dietary allowances,[47] the U S Food and Nutrition Board has stated its recommendations for this nutritive factor as "niacin equivalents," a term which includes both preformed niacin and that expected to be formed in the body from the tryptophan of the diet. Thus, a food which provides tryptophan plentifully may be an excellent purveyor of niacin even though its preformed niacin content is not high A quart of milk daily, for instance, will suffice to prevent pellagra, although its content of niacin is relatively low. How its high content of tryptophan may be counted on to furnish additional niacin, which must be added in calculating its mg equivalents of niacin, is shown in Figure 85, below.

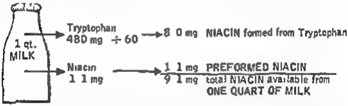

Figure 85 Calculating the "niacin equivalents" in a quart of milk To the niacin that is carried as such in the milk (1 1 mg per quart) should be added the amount that may be expected to be formed in the body from its tryptophan content (480 mg per quart) Assuming that approximately 1 mg of niacin will be formed for each 60 mg of tryptophan (480 − 60), 8 mg niacin might be expected to arise from the tryptophan content of the milk, bringing the total niacin equivalents of a quart of milk up to 9 1 mg

Horwitt[46] has outlined the procedure for calculating niacin equivalents of the diet as follows assume that the various proteins of a normal mixed diet contain an average of 1 per cent tryptophan, take 1 per cent of the grams protein intake, convert this figure for tryptophan into milligrams and divide by 60 to give mg niacin expected to be formed from protein intake, to this add the preformed niacin in the food to give total niacin mg equivalents of the diet For example

protein per day, 1%
ied by diet, 700 mg
n

[46] Horwitt, M K, J Am Dietet Assoc, 34, 914, 1958, and Goldsmith, G A, Am J Clin Nutr, 6, 479, 1958

[47] Recommended Dietary Allowances, National Research Council, Pub 589, special note on Niacin, pp 13–15, 1958

The new allowances recommended for niacin by the Food and Nutrition Board (1958) are as follows:

	Niacin mg equiv
Men (larger amounts for higher calorie allowances)	18–21
Women	17
Pregnant and Lactating Women	19–20
Girls, 13–19	16–17
Boys, 13–19	21–25

It should not be difficult to secure the recommended amounts of niacin on a well balanced diet such as is advised for meeting other nutritive requirements The group of foods listed on page 241, as sufficient to furnish the allowance for riboflavin, may be assumed to provide about 10 5 to 11 mg. preformed niacin, these foods also supply high quality protein generously, so that the tryptophan content of the protein intake would be sufficient to bring the total niacin equivalents up to the daily allowance, or more If milk, meats, whole grain or enriched cereals, leafy and other vegetables are used fairly freely, the diet will be protected against shortage of niacin, when such practices are not followed, the amounts of niacin provided, though above the level necessary to prevent pellagra, may be less than the optimum quantities recommended for health.

OTHER VITAMINS OF THE B-COMPLEX

In order that the student may not be too confused by the number and variety in functions of these lesser known B vitamins, it seems best to point out certain facts common to them as a group. Although they differ widely as to chemical nature, ranging in complexity from the large molecule of folic acid to the relatively simple one of inositol (which has the same empirical formula as glucose, $C_6H_{12}O_6$), they qualify as vitamins because they are organic substances that are essential for *growth* and *for nutritional welfare*. It is important to note that practically all of the B vitamins can be *synthesized by bacteria*, including the bacteria normally found in the human intestinal tract; several can be formed in the body from *precursors* (as niacin can be formed from the amino acid tryptophan), which are either supplied in the diet or formed in metabolic processes in tissues Hence, it is difficult to say to how great an extent the requirement may be met through synthesis within the body and how much will need to be furnished in the diet. With certain species of animals, intestinal synthesis is apparently sufficient to supply all they need of these "minor" B vitamins Most of them are presumably essential for human nutrition but, because they are needed in small amounts and widely distributed in foods, deficiencies would seldom, if ever, occur on human diets that are adequate in other essential factors.

All of these B vitamins are *water-soluble*, but they differ as to relative stability to heat, light, oxidation, etc Most of them have been shown

to function by forming part of *enzymes or co-enzymes* that catalyze some chemical reaction essential in the complicated metabolism by which tissues live and grow. The research by which their individual roles in "intermediary metabolism" are being studied involves chemistry that is so complex as to make it impossible to relay the findings to the elementary student Suffice it to say that research in this field is very active, with new facts constantly coming to light In the effort to simplify this material, we will spare the student historical data, except to call attention to the fact that the latest of these vitamins to be isolated was vitamin B_{12} in 1948, so that it is not beyond possibility that still others may yet be discovered

Vitamin B_6

This name was first given to an unidentified factor necessary for growth and for prevention of a particular type of skin disorder in rats, similar to that produced by lack of essential fatty acids Dogs and pigs on B_6-deficient diets develop a certain type of anemia, as well as epileptic-like convulsions, it is also required by pigeons and chickens Three closely related chemical substances have been shown to have vitamin B_6 activity—*pyridoxine, pyridoxal,* and *pyridoxamine;* the term vitamin B_6 is used to designate this group of biologically active substances Each of them is built around the same chemical nucleus (pyridine), which is the nucleus also found in nicotinic acid and nicotinic acid amide

Vitamin B_6 has been demonstrated to occur in important enzyme systems involved in the metabolism of *amino acids,* and hence is essential to normal metabolism of proteins It may also function in some way in fat metabolism, since it seems to be interrelated in metabolism with the *essential fatty acids* Not only is the skin disorder very similar when caused by lack of either of these nutritive factors, but giving plenty of either one of these factors alleviates the effects (skin lesions) caused by lack of the other The relation of its lack to anemia is not yet understood

Until recently little was known of the value of vitamin B_6 in human nutrition, although it (or derivatives) was known to occur in the blood, tissues, and urine of man Experimental production of pyridoxine deficiency in men and infants (both by feeding a diet deficient in pyridoxine and by administering an antagonistic substance that blocks its activity) caused symptoms (skin and tongue lesions, and growth failure in infants) similar to those induced in animals by pyridoxine deficiency [49] An interesting abnormality of protein metabolism was the loss of ability to convert amino acid to niacin Administration of pyridoxine led to disappearance of all the abnormalities induced by its lack These reports seem to indicate that vitamin B_6 is essential for man, especially for normal protein metabolism.

[49] Mueller, J F, and Vilter, R W, J Clin Invest., 29, 193, 1950, Greenberg, L D, *et al*, Arch Biochem, 21, 237, 1949, McGanity, W J, *et al*, J Biol Chem., 178, 511, 1949, Synderman, Carretero, and Holt, Fed Proc, 9, 371, 1950

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All of these B vitamins are *water-soluble*, but they differ as to relative stability to heat, light, oxidation, etc. Most of them have been shown

processes by which the tissues utilize foodstuffs and build one type of substance over into another that it has been said to "sit at the crossroads of metabolism." *Coenzyme A*, as it is called, acts as a carrier for *2-carbon fragments* (acetyl groups) formed in metabolism, thus enabling them to be used in a wide variety of chemical reactions. It is involved in the primary pathways by which carbohydrates, fatty acids and amino acids are broken down to carbon dioxide and water and yield energy for the body. By splitting off or adding on acetyl groups, intermediate products of carbohydrate metabolism can be used to make certain amino acids (for protein synthesis), fatty acids (in building fat from carbohydrate) and such important sterols as cholesterol and the adrenocortical hormones mentioned above. For a diagram of the strategic position of coenzyme A at the "crossroads of metabolism," see Figure 125, page 384.

Since pantothenic acid is obviously so important (through coenzyme A) for manifold chemical changes in body tissues, it seems strange that no definite symptoms of its lack have yet been demonstrated in man. Perhaps this is because, while it is needed only in small amounts, it is widely distributed in foods and may also be synthesized in the body or by intestinal bacteria. The best food sources are liver, yeast, meats, whole grains, and milk, most other foods furnish it in lesser amounts. No human requirement has been set.

Pantothenic acid seems to be associated in metabolism in some way with riboflavin. There is some similarity in symptoms of deficiency, and administration of either one of these vitamins results in an increased content of the other in the blood. Pantothenic acid deficiency is also sometimes present in pellagra, along with deficiencies of niacin and riboflavin.

Biotin

Biotin was first recognized as a growth requisite for bacteria and yeasts, but is now known to be a dietary essential for many species of animals, including man. Since it is present in most foods and is needed in exceedingly small amounts, the natural occurrence of biotin deficiency in man is unlikely. Its biological activity is doubtless related to the sulfur-containing group it carries (as previously stated, biotin and thiamine are the only vitamins that contain sulfur). Its mode of action in promoting growth and cell respiration is not known exactly, but it has been suggested that it is concerned in metabolism of carbohydrate, perhaps in the reactions by which carbon dioxide is split off from, or added to, various intermediary products. Biotin is found in almost all plant and animal tissues, normally in combination with protein and concentrated particularly in young, rapidly growing cells or organisms.

The fact that biotin is a dietary essential for human beings was shown through induction of a deficiency of it by giving a substance that prevented the body from deriving it from its normal sources. Such de-

The question of whether this vitamin is essential for humans was settled in a rather surprising way. Suddenly in 1951 babies (6 weeks to 6 months old) fed solely on a commercial infant food began to develop convulsions, those who had been fed the company's liquid (canned) product became seriously ill, while others fed a similar formula sold in dry, powdered form were all right. Dr. Kline of the U. S Food and Drug Administration, recognizing the similarity of these convulsive seizures to those seen in young rats deprived of vitamin B_6, suggested the infants might be ill because of lack of this vitamin, and when it was given to the affected babies they promptly recovered.[49] The heat used to sterilize the liquid product in cans had been high enough to destroy the group B_6 vitamins, a fact no one had noticed or would have thought important, if they had known of it Since the proof of its necessity for normal human nutrition, this company has added vitamin B_6 to its products and other manufacturers of infant foods take care that it is not destroyed in processing

The occurrence of vitamin B_6 in foods follows the general distribution of other vitamins of the B-complex The best sources are liver, muscle meats, some vegetables, and whole grain cereals In milling of patent flour, half of the pyridoxine content of wheat is lost, and it is not added in enrichment of white flour. The roasting or stewing of meat causes 20 to 50 per cent loss in its pyridoxine content.

Pantothenic Acid

This vitamin was discovered as a factor that promoted growth of yeast and green plants, and also prevented a skin disease in chicks, the name pantothenic acid was given to it as indicative of its very wide occurrence in nature It is the product of the linkage of two fairly simple organic substances, a derivative of butyric acid and the amino acid alanine, the synthetic vitamin is available in the form of its calcium salt

A deficiency of pantothenic acid affects many tissues, it results in bald spots, graying of hair, and skin disorders in rats, ulcers in the intestinal tract in dogs, and a "goose-stepping" gait in pigs, in many species degenerative changes are found in the nervous system and especially in the *adrenal glands.* The role of pantothenic acid in the activity of the adrenals was elucidated when it was shown to be part of a coenzyme needed for making the lipoid substances (sterols), which are formed in the outer portion (cortex) of these ductless glands and are passed into the blood as hormones (cortisone and two related hormones). These hormones have important regulatory influences on metabolism, indeed are essential for life

The role of the coenzyme in which pantothenic acid is incorporated has been shown by recent research to be concerned in so many chemical

[49] "Vitamin B_6 in Human Nutrition," Report of the Tenth M & R Conference, M. & R Laboratories, Columbus, Ohio, 1953

sulted in formation and development to maturity of very many new red blood cells. Anemias that develop during pregnancy, infancy, and sprue respond well to treatment with folic acid, while those due to dietary lack of iron and certain other causes are not relieved by it. In pernicious anemia, there is some initial response (with increased level of red cells) but not as marked as after giving much smaller amounts of vitamin B_{12}, while the nervous symptoms often seen in this disease cannot be cured by treatment with folic acid. A derivative of folic acid has been used with some success in treatment of leukemia, but its effects wear off as the body develops resistance to it.

Although folic acid is obviously an essential nutritional factor, it has not yet been established to how great an extent man is dependent upon food for his supply of it. Probably under normal conditions the amounts synthesized by intestinal bacteria will suffice for his needs, yet it would be a factor of safety to have some in the food. It has been calculated that the average man probably needs somewhat less than one milligram per day. Determination of the amounts present in foods was handicapped by the fact that much of it was present in bound forms and had to be set free by certain enzymes before the total available amounts could be determined. In general, foods of high or moderately high folacin content are leafy vegetables (fresh), liver, kidneys, fresh green vegetables (such as asparagus, green beans, peas, and broccoli), whole grains, and nuts including peanuts; most other foods are only fair or poor sources of this vitamin.[50]

In metabolism, folic acid is converted to a substance known as *citrovorum factor*; this substance occurs in the urine, where it is increased in amount after doses of folic acid. It seems to be established that folic acid has to undergo transformation to citrovorum factor (or some closely related substance) before it can carry out its functions in the body. Vitamin C (ascorbic acid) has been shown to augment or facilitate the conversion of folic acid to citrovorum factor,[51] and there are other evidences of a close metabolic relationship between these two vitamins.

Folic acid (or some substance into which it is transformed in living cells) also shares in another metabolic process with other vitamins. It has been shown to be involved in the metabolism of several amino acids (glycine, tyrosine, glutamic acid, and histidine) and is especially related to the metabolism of methionine, an amino acid that contains a "labile methyl" group. Its role in the formation of methyl groups that can be transferred from one compound to another (and are hence referred to as labile methyl) is interrelated with and shared by both vitamin B_{12} and choline, and will be treated more fully under the discussion of choline.

[illegible]

ficiency was first induced in humans by use of a diet low in biotin, supplemented by large amounts of dried egg white. Egg white is known to contain a protein substance, avidin, which combines with biotin so as to render the latter unabsorbable from the intestinal tract. This artificially produced biotin deficiency resulted in man in pathological changes in the skin and tongue, loss of appetite, nausea and a low-grade anemia, lassitude and intense depression. Injections of biotin brought marked improvement of symptoms in 3–4 days. In later experiments biotin deficiency was produced as a result of giving "sulfa" drugs by mouth, thus destroying the intestinal bacteria and depriving the body of biotin formed by intestinal synthesis, this induced similar symptoms, which were cured by giving biotin. Although the existence in raw egg white of a substance that binds biotin so firmly as to render it unavailable to the body is of scientific interest, it is unlikely that biotin deficiencies would occur from this cause under normal conditions The action of sulfa drugs (or other antibiotics taken by mouth) in depriving the body of various vitamins normally supplied to some extent by intestinal synthesis is something that must be taken into account in medicinal treatment.

Folic Acid, or Folacin

This substance, discovered in spinach and alfalfa as a growth-promoting factor for certain microorganisms, was named folic acid to indicate its abundance in green foliage It was later shown to be closely related to, if not identical with, substances whose lack caused anemia and gastrointestinal disturbances in monkeys and chicks, and it was also shown to be needed for growth of animals Finally the isolation and synthesis of folic acid was accomplished It is a rather complex compound formed by the linkage of a phosphorescent pigment (pterin) with para-aminobenzoic acid and another amino acid, glutamic acid; there may be one, three, or seven glutamic acid groups in the molecule, and conjugated forms also occur, so these compounds are sometimes referred to as the folic acid group The American Institute of Nutrition has adopted the simpler name of *folacin* for the substance previously known as folic acid, or pteroylglutamic acid For monkeys, chicks, and some other animals it must be furnished in the food, rats and dogs get enough through synthesis by intestinal bacteria to supply their needs.

One or more of the folic acid group are essential (probably as coenzymes) for the metabolic processes by which nucleic acid and nucleoproteins are formed, and hence are important for all body cells, but especially for the building of new red blood cells Immediately after its synthesis folic acid was tried therapeutically on patients suffering with anemia, and strikingly beneficial results were produced in at least five forms of "macrocytic" anemia, including pernicious anemia. In macrocytic anemia, the red blood cells are fewer in number and larger in size than normal, administration of folic acid by mouth or by injection re-

No quantitative estimates of human requirement or content in foods are available If the normal adult needs any vitamin B_{12} from foods, this need must be minute, at the level of a few micrograms, in persons whose intestinal absorption is good, synthesis by intestinal bacteria may be sufficient to meet their needs. Smith[32] believes it probable that the only primary source of this vitamin in nature is synthesis by microorganisms It is probably not present at all in vegetable foods and is so closely associated with foods that carry animal protein that it has been called an "animal protein factor" Liver, kidney, and fresh muscle meats seem to be the best dietary sources, while milk and milk products carry much smaller amounts of this vitamin

Choline

This substance is sometimes included as a member of the B-vitamin group Its vitamin activity has been demonstrated chiefly on microorganisms, plants, or lower animals, although it is known to function in human metabolism, it is questionable whether it should be classed as a vitamin since, given the proper precursors, it can be formed in the tissues Even if some supplementary amounts need to be furnished in the diet, there is little likelihood of shortage as it is present in adequate amounts in normal dietaries

Choline is a methylated nitrogen-containing base which has long been known as a constituent of phospholipids, which in turn are built into certain tissues and play an important role in the metabolism of fats, especially in the liver. When choline deficiency was induced in dogs and rats, there was excessive deposition of fat in the liver (fatty liver), hemorrhagic lesions in the kidneys, sometimes leading to later development of high blood pressure and cirrhosis of the liver Administration of choline prevented the abnormal accumulation of fat in the liver, which commonly develops in depancreatized dogs maintained on insulin, or in normal rats fed diets high in fat or cholesterol The action of choline in preventing development of fatty liver is said to be a "lipotropic" activity

Choline is also sometimes referred to as a "labile-methyl factor" The methyl group or radical (CH_3) is found in many organic substances but in most of them it is fixed and not detachable, when it is present in such a form that it can be transferred from one compound to another, it is called "labile methyl" The body has a "pool" of labile methyl, contributed from various sources, which it uses for such purposes as the formation of creatine (important in muscle metabolism) and for methylating certain substances for excretion in the urine The dietary sources of labile methyl are choline (in phospholipids in food), the amino acid methionine (from food proteins), and another substance, betaine, in addition, there is some newly synthesized methyl, for the utilization of which folic acid or vitamin B_{12} is apparently essential To some extent,

[32] Smith, E L., "Vitamin B_{12}," Nutr Abst & Rev., 20, 795, 1951

Vitamin B_{12} (Cobalamin)

For a long time it had been apparent that liver and concentrates made from it contained some substance that was very potent in restoring a normal blood picture in patients with pernicious anemia, an "anti-anemia factor." Folic acid was not the substance, since it had to be given in relatively large amounts and did not cure all the symptoms of pernicious anemia After many chemical purifications, chemists isolated this "active principle" from liver and gave it the name of vitamin B_{12}. it is a red, crystalline substance that has a large molecule and contains phosphorus and cobalt, the latter element probably being associated with its blood-forming potency. As little as 1 to 5 *micrograms* (*millionths of a gram*), injected intramuscularly each day in a pernicious anemia patient, will result in restoration of a normal red blood cell count and gradual disappearance of all the other symptoms of pernicious anemia.

The complete efficacy of vitamin B_{12} in relief of pernicious anemia led to the belief (since borne out by study) that it represented the "extrinsic factor" supposed to be essential for normal formation of erythrocytes (red blood cells) in Castle's theory: extrinsic factor + intrinsic factor → erythrocyte maturation factor The extrinsic factor was supposed to be furnished in food and to interact with an intrinsic factor found in normal gastric juice (but not in that of pernicious anemia sufferers) to form the red cell regenerative factor. Since it takes much larger amounts of vitamin B_{12} to be effective in restoring the blood to normal if it is given to pernicious anemia patients by mouth, the function of "intrinsic factor" is thought probably to set free the antianemia-factor, vitamin B_{12}, from a combination with protein and so to make it available for *absorption* from the intestinal tract Vitamin B_{12} obviously does not have to be activated by interaction with the factor in normal gastric juice, as it is so potent when injected directly into the tissues. Since vitamin B_{12} is formed by bacteria in the intestinal tract of patients with pernicious anemia as well as of healthy persons, the primary defect in pernicious anemia is now thought to be lack of "intrinsic factor" (in the gastric juice) to promote the absorption of B_{12}

Vitamin B_{12} has other nutritive uses besides its "anti-pernicious anemia" effect It has growth-promoting properties for microorganisms and several species of animals, and possibly in some cases for children when growth has been retarded by faulty diet It seems to function in the metabolism of nucleic acid (in cell nuclei) and participates with choline and folic acid in the metabolism of the amino acid methionine. When plenty of B_{12} is available, less of either choline or methionine is needed to prevent certain deficiency symptoms Symptoms of deficiency of vitamin B_{12} develop more readily if metabolism is speeded up by giving thyroid or iodinated casein, so that the amount required seems to be partly dependent on the metabolic rate

breads and cereals if these are used. Liver served at least once a week, a few tablespoonfuls daily of wheat germ, bran, or crude molasses, or tablets of dried brewers' yeast, are inexpensive ways to reinforce the intake of B vitamins for those whose diet consists largely of refined and canned foods. From such natural sources one gets a better *balanced* ration of *all* these B-complex vitamins than by taking individual synthetic vitamins or "enriched" foods to which large quantities of some and none of the others may have been added There is considerable evidence to prove that the relative proportions of nature's mixtures of B vitamins in foods are those best adapted for promoting health

A summary of the main food sources of B-complex vitamins and their general effects in promoting health is given in Figure 86.

QUESTIONS AND PROBLEMS

1. Enumerate seven vitamins that are known as B-complex vitamins For each of the following, give its chief use (or uses) in the body and the symptoms that are characteristic results of a deficiency of it in the diet. thiamine, riboflavin, niacin.

2 Explain what nutrients are added to white wheat flour in the "enrichment program" Does this make enriched white bread equal in all respects to that made from whole wheat flour? If not, explain in what respects whole wheat is nutritionally superior

3 Is pellagra a clear-cut deficiency disease due to lack of niacin alone? If not, enumerate what other nutritive deficiencies are likely to occur as a result of a diet consisting mainly of corn meal and grits, white flour and rice, and fatty salt pork What foods introduced into the diet as a result of making a home garden, and keeping a cow and hens will have pellagra-preventing properties? What foods could be added to further improve the diet, if money were available to buy them?

4 Either make out a day's menus for what you would consider an attractive diet, or set down your actual food intake for an average day. Specify the amounts of each food consumed Consult the tables in the preceding chapter and in the Appendix for content of foods in protein, thiamine, riboflavin, and niacin Add up the total quantities of thiamine and riboflavin which would be provided in the day's diet that you planned or consumed Calculate how many niacin equivalents might be expected to be furnished from tryptophan in the protein consumed, taking tryptophan as 1 per cent of the protein and dividing this number, in milligrams, by 60 (60 mg. tryptophan gives an average of 1 mg niacin) Add this to the niacin furnished in the food to get total available niacin.

5 Look up, or calculate as directed in the preceding chapter, the recommended allowance for each of these three vitamins for a person of your sex, size, and degree of activity How does the intake of each vitamin in the calculated diet compare with the recommended allow-

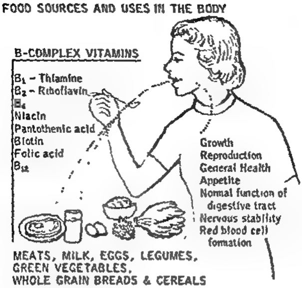

Figure 86

an abundance of any one of these sources of labile methyl may be said to "spare" the others, or at least to partially make up for a shortage of one of the others. Since the amount of choline needed will be influenced by what other sources of labile methyl are available, it is not possible to estimate the human requirement In any event, a certain amount of it will be needed for its functions in fat metabolism and for building into body tissues

For the student with very limited knowledge of chemistry, it may be that even the simplified explanations given here as to how the vitamins bring about their effects on metabolism in the tissues may be more confusing than enlightening Even such students, however, can gain some ideas about how far the chemists have gone in following the activities of the vitamins within body tissues and explaining why small amounts of these substances are essential for facilitating chemical processes necessary to health.

HOW TO GET B-COMPLEX VITAMINS IN THE DIET

The number of different vitamins in the B-complex need not distress the elementary student, since they are found together in foods If the diet furnishes plenty of the important B_1 (thiamine), B_2 (riboflavin), and niacin, it is probable that sufficient amounts of the less well-known B vitamins will be provided at the same time Although present in minor amounts in many foods, the staple foods upon which we depend chiefly for B-complex vitamins are *meats, milk, eggs, legumes,* and *green vegetables,* with considerable additions from *whole grain*

breads and cereals if these are used Liver served at least once a week, a few tablespoonfuls daily of wheat germ, bran, or crude molasses, or tablets of dried brewers' yeast, are inexpensive ways to reinforce the intake of B vitamins for those whose diet consists largely of refined and canned foods From such natural sources one gets a better *balanced* ration of *all* these B-complex vitamins than by taking individual synthetic vitamins or "enriched" foods to which large quantities of some and none of the others may have been added There is considerable evidence to prove that the relative proportions of nature's mixtures of B vitamins in foods are those best adapted for promoting health

A summary of the main food sources of B-complex vitamins and their general effects in promoting health is given in Figure 86

QUESTIONS AND PROBLEMS

1 Enumerate seven vitamins that are known as B-complex vitamins For each of the following, give its chief use (or uses) in the body and the symptoms that are characteristic results of a deficiency of it in the diet, thiamine, riboflavin, niacin

2 Explain what nutrients are added to white wheat flour in the "enrichment program" Does this make enriched white bread equal in all respects to that made from whole wheat flour? If not, explain in what respects whole wheat is nutritionally superior

3 Is pellagra a clear-cut deficiency disease due to lack of niacin alone? If not, enumerate what other nutritive deficiencies are likely to occur as a result of a diet consisting mainly of corn meal and grits, white flour and rice, and fatty salt pork. What foods introduced into the diet as a result of making a home garden, and keeping a cow and hens will have pellagra-preventing properties? What foods could be added to further improve the diet, if money were available to buy them?

4 Either make out a day's menus for what you would consider an attractive diet, or set down your actual food intake for an average day. Specify the amounts of each food consumed Consult the tables in the preceding chapter and in the Appendix for content of foods in protein, thiamine, riboflavin, and niacin Add up the total quantities of thiamine and riboflavin which would be provided in the day's diet that you planned or consumed. Calculate how many niacin equivalents might be expected to be furnished from tryptophan in the protein consumed, taking tryptophan as 1 per cent of the protein and dividing this number, in milligrams, by 60 (60 mg tryptophan gives an average of 1 mg niacin) Add this to the niacin furnished in the food to get total available niacin

5 Look up, or calculate as directed in the preceding chapter, the recommended allowance for each of these three vitamins for a person of your sex, size, and degree of activity. How does the intake of each vitamin in the calculated diet compare with the recommended allow-

ance? What foods fairly rich in these three vitamins might be used to increase the thiamine, riboflavin, and niacin content of the diet?

6 From the figures given below, how much liver would be required to add [illegible] milligrams of niacin (¼ day's allowance for moderately active man) to the diet? How much dried brewers' yeast to contribute 1 milligram of riboflavin (⅔ daily allowance for the average weight woman)? How much wheat germ to provide 0.5 milligram of thiamine (approx. ⅓ daily allowance for moderately active man)? Comparing data on equal weight basis (10 gm each), which of these substances is richest in thiamine, in riboflavin, in niacin?

	Weight, gm	Measure	Thiamine, mg	Riboflavin, mg	Niacin, mg
Liver, beef, fried	74	2 slices, 3 × 2¼ × ⅜ in	0 179	2 56	10 10
" " "	10		0 026	0 40	1 48
Yeast, dried, brewers'	10	4 level teaspoons	0 969	0 54	3 62
Wheat germ	10	2 level tablespoons	0 205	0.08	0 46

7 Give the chief nutritional functions for each of the following vitamins folic acid, vitamin B_{12}, vitamin B_6, and pantothenic acid. Can you give any examples of interrelations between different B-complex vitamins? What types of foods, used freely in the diet, will ensure a sufficient intake of the whole group of B-vitamins?

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Fat-Soluble Vitamins

AT FIRST glance it might seem that the problems of fat-soluble vitamins would be simpler than those concerned with water-soluble vitamins —fat-soluble vitamins are much fewer in number, more stable to heat, and less likely to be lost in the cooking and processing of foods But other complicating factors appear which are peculiar to this type of vitamin Chief among the traits distinctive of fat-soluble vitamins are the following

(1) Their vitamin activity is not confined to a single substance but *several* chemically similar substances will produce a like effect on the body, although often in varying degree A letter of the alphabet is used to designate the group

(2) There exist in foods certain *precursors or provitamins*, themselves without vitamin activity, which give rise to fat-soluble vitamins when taken into the body In the case of vitamin D a precursor is present in the skin, which is converted to the

VITAMIN A

The presence of vitamin A in certain fats was first detected by reason of its effect in promoting growth. This discovery was made in 1913, independently by Osborne and Mendel and by McCollum and Davis. Rats fed on purified foodstuffs with lard as the only fat ceased to grow, developed soreness of eyes, and eventually died, with butterfat or ether extract of egg yolk in the diet, rats were protected from these ill effects. Further experiments showed that cod liver oil is very rich in this growth-promoting, health-protecting factor, whereas most commercial fats and oils behave more like lard. Although pure vitamin A is now available, obtained either by synthesis or by isolation from natural sources, we still depend chiefly on fish liver oils (or extracts made from them) for concentrated sources of this vitamin.

Properties and Animal Sources

Vitamin A is almost *colorless, insoluble in water, soluble in fats* and fat solvents, and fairly *stable to heat*, but may be *destroyed by oxidation* at high temperatures or by exposure to ultraviolet light. Fats and oils lose vitamin A content (by oxidation) as they become rancid, substances that inhibit this oxidation (antioxidants) are often present in unrefined oils but are usually removed when oils are refined for food use Hence, we depend mainly on storage in a cool, dark place (refrigerator) to protect fats and oils from vitamin A loss.

Two slightly different *forms* of this vitamin, A_1 and A_2, are known, but the latter occurs only in fresh-water fish and birds that feed on these fish Vitamin A_1 is found in the livers and body fat of salt-water fish, and in other foods of animal origin, such as liver, milk, butter, and egg yolk. Since both *forms* of the vitamin have the same physiological effects, we need make no distinction between them.

Animals get their vitamin A either directly or indirectly from plant sources. Fish eat smaller fish or crustaceans which, in turn, have fed on marine plants that contain the precursors of this vitamin. Herbivorous animals eat green plants that carry provitamins and convert these substances into the vitamin itself in their bodies; carnivorous animals get the vitamin from feeding on plant-eating animals. The cow and the hen are useful to man by converting provitamins in plant foods into the vitamin A in milk fat, and eggs. Since *some provitamins in the diet escape* this conversion, *milk fat* and egg *yolk* contain a *mixture* of both vitamin A and its plant precursors. The relative amounts of each depend partly on the food of the animal and partly on its species, or even breed, for instance, milk from Holstein cows contains a higher proportion of vitamin A, and that from Guernsey cows carries less vitamin A and more of the provitamins.

Plants as Sources of Provitamins A

Vitamin A as such is not found in the vegetable kingdom, but the *provitamins A* are found instead in plants They are bright *yellow* or *orange-yellow* pigments, which give the color to carrots, sweet potatoes, squash, pumpkin, apricots, yellow peaches, and corn They are also present in all green vegetables, although there their color is masked by that of the green pigment, chlorophyll As the quantity of these vitamin A precursors roughly parallels that of chlorophyll, being found most richly in thin, green leaves, the chlorophyll may be concerned in their formation. Young, rapidly growing plants or parts of the plant contain more than do older plants

Three of these "precursors" are known as *carotenes* (alpha-, beta-, and gamma-carotene), and a fourth is cryptoxanthin When these substances are taken into the body they give rise to vitamin A, the chief site of conversion of provitamin to vitamin A seems to be in the intestinal wall (during absorption into the body). Although beta-carotene is capable of being split to give two molecules of vitamin A (twice as much as the other precursors), it is now questioned whether any higher yield of vitamin A is obtained from this substance in the body than from other types of carotene Of course some of the provitamins in food may escape absorption from the intestine, and one cannot be sure that those that are absorbed will be completely converted to vitamin A There are differences in species and in individuals as to how well they utilize carotenes (degree of utilization varies in man from 30 to 70 per cent),[1] but it is usually estimated that *less than half of the carotene* intake may be expected to be *transformed into vitamin A*. Foods that contain carotenes are said to have *vitamin A value*, even though they do not carry this vitamin in a preformed condition

Effects of Lack of Vitamin A

Vitamin A is essential for growth, for vision, and for maintenance of epithelial tissues in a healthy state Hence, a diet that contains amounts of vitamin A (or its precursors) insufficient to meet the needs of human beings will in time cause *stunting of growth, lack of ability to see well in dim light* (night blindness) or more serious eye troubles, and diseased conditions of the *skin* and membranes lining the *respiratory passages and the digestive and genitourinary tracts*

The eye is one of the first organs to show effects of vitamin A lack, because this vitamin is a *constituent of a pigment in the retina* When light falls on the retina this pigment, called visual purple, is bleached to another known as visual yellow and, as a result of this change, images are transmitted to the brain through the optic nerve. In the dark, the

[1] With, T K, Absorption, Metabolism and Storage of Vitamin A and Carotene, Chap VII Humphrey Milford, Oxford, Eng, 1940

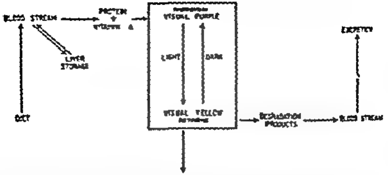


Figure 67 Diagram of visual cycle, showing why vitamin A from the blood stream is needed to rebuild the pigment, visual purple, in the eye after exposure to light. (Gordon and Sevringhaus, Vitamin Therapy in General Practice, Year Book Publishers, Inc.)

vitamin A-containing visual purple is rebuilt, but there is always some loss of degradation products, which necessitates new supplies of vitamin A brought by the blood If vitamin A is at a low level in the blood, normal vision will be restored slowly and "dark adaptation" of the eyes will be faulty Tests for dark adaptation seemed to offer a way of detecting early vitamin A deficiency, but experience has shown that this function is influenced by too many other factors to be an infallible index of the adequacy of vitamin A in the diet. Moreover, stores of vitamin A in the liver can be drawn on to replenish the vitamin A in the blood stream, so that a low level of this vitamin in the blood may not appear until late in a deficiency But lack of vitamin A is one of the common causes of *night blindness*, and a good many cases do respond favorably to extra doses of this vitamin It has been shown to be prevalent in regions where the diet is low in vitamin A (China, Ceylon, Newfoundland, etc.), and occurs fairly frequently among supposedly well-fed Americans Automobile accidents in night driving may sometimes result from this cause, especially if the driver sees poorly after exposure to the bright headlights of on-coming cars.

An even more delicate test for detecting deficiency of vitamin A by eye examination has been suggested by Kruse.[2] This depends on examination of the conjunctiva, the membrane lining the eyelids and covering the front of the eyeball, by means of a biomicroscope. It is claimed that one of the first symptoms of vitamin A lack is the appearance of tiny lumps or puckers (due to piling up of damaged epithelial cells), which may be seen on the conjunctiva even before failure of dark adaptation occurs Kruse reported that over half of the persons in a low income group that he examined showed these microscopic eye lesions, and that vitamin A therapy was curative in some cases. However, it is seriously questioned whether appearance of these lesions con-

[2] Kruse, H D., Pub Health Report, 56, 1301, 1941

stitutes specific evidence of vitamin A deficiency McLester has cautioned "Not all instances of true Bitot's spots respond to the administration of vitamin A, and it is apparent that many of these lesions are due to causes other than a deficiency of this factor."[3]

One of the chief functions of vitamin A is to maintain the health of *epithelial tissues*, namely the skin and membranes that line all passages which open to the exterior of the body, as well as glands and their ducts When deprived of an adequate supply of vitamin A, these tissues undergo changes that lead to a peculiar type of horny degeneration called keratinization Damage to the mucous membranes lining the mouth, throat, nose, and respiratory passages is one of the earlier effects of vitamin A lack In addition to general deterioration of the cells, these membranes lack their normal secretions and there is loss of the little filaments, called cilia, which by constant movement aid in keeping the membrane surface clean As bacteria have easy access to these parts, susceptibility to *colds, sinus trouble, sore throat, and abscesses in ears, mouth, or salivary glands* are common manifestations of insufficient vitamin A in the diet. Similar damage to membranes lining the alimentary tract may allow bacteria to penetrate into the stomach or intestinal wall, whence they may be carried in the blood stream to other parts of the body

[illegible]
damaged (Courtesy of Dr Bloch of Copenhagen.)

[3] McLester, J S, and Darby, W J, NUTRITION AND DIET IN HEALTH AND DISEASE. p 252, Saunders, 6th ed, 1952

Figure 89 Xerophthalmia in a puppy due to feeding a diet deficient in vitamin A Note the swollen lids and sticky discharge from the eyes Full recovery after administration of vitamin A is shown in the lower picture (Courtesy of Doctors Steenbock, Nelson, and Hart)

The frequency of infections of various kinds (especially of the respiratory tract) in *severe* vitamin A deficiency has led to the use of concentrated preparations of this vitamin for the prevention and treatment of colds and other similar infections. Statistics as to whether extra vitamin A raises resistance to infections are conflicting, but are mostly on the negative side. Probably vitamin A shares with other vitamins in promoting health of tissues and is "anti-infective" chiefly in the sense that it helps to keep healthy the lining membranes that are the "first line of defense" to prevent entrance of bacteria into the body. If there has been previous deficiency of this vitamin in the diet, extra doses of it will be helpful in rebuilding stores of it in the liver and restoring damaged epithelial tissues to health

More prolonged lack of vitamin A results in dry and scaly skin, with plugs of horny material about the hair follicles, and in the eye disease known as ***xerophthalmia***. In the latter disease, the secretion of tears

is stopped, the eyes are sensitive to light, the lids become swollen and sticky with pus, bacteria may invade the eye itself and cause ulcers of the cornea which lead to blindness if the disease is not arrested Xerophthalmia is most often seen in *infants* or undernourished *children*, and may be prevented by including in the diet some good source of vitamin A, such as cod liver oil, butter, whole milk, or egg yolk It is of frequent occurrence in parts of the world where there is almost no fat and few green vegetables in the diet, e g, among the poor on preponderantly cereal diets in India, China, Egypt, and parts of Africa, where it may be the underlying cause of much blindness In older children and young adults, too low a supply of vitamin A may predispose to tuberculosis

Vitamin A is also essential for proper formation and maintenance of tooth enamel and health of gums, for health of the membranes that line the bladder and urinary passages, uterus, vagina, etc, and for the welfare of the sex glands Some investigators believe that lack of this vitamin is associated with a tendency toward formation of kidney or bladder stones, or to minor kidney infections and less efficient secretion of urine Others have found nervous lesions to develop in animals on vitamin A deficient diets, it is stated that the bony structure ceases to grow (due to vitamin A lack) before growth of nervous tissue is inhibited, and that the resultant crowding of nerves in the bony cavities of the skull and spinal column is the cause of nervous lesions It is certain that this vitamin is needed in considerable amounts to insure optimum *growth* (Fig 90) and successful *reproduction* (see Figs 91 and 92 on page 274).

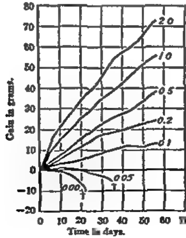
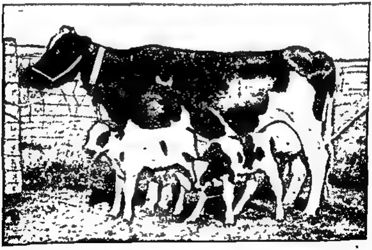


Figure 91 A disaster in reproduction caused by feeding a ration made from wheat straw, wheat meal, and wheat gluten, with common salt The cow was shaggy-coated, slow and sleepy in movement, and had a tendency to drag her hind feet The calf was born prematurely and died (From Research Bulletin 17, University of Wisconsin Agricultural Experiment Station)



Vitamin A in the Body

Although it is not yet clear just how vitamin A acts to promote health of tissues, chemical and physical methods for detecting and measuring it in blood and tissues have enabled us to follow its course within the body

First, both the vitamin itself and carotenes in the food must be absorbed through the intestinal wall They are known to pass, along with absorbed fats, into the lymph (later emptied into the blood), and the presence of fat favors their absorption. Bile is essential for the absorption of carotenes Any factor that lowers fat absorption will also affect the absorption of fat-soluble vitamins unfavorably, in disorders such as jaundice and celiac disease, much of the vitamin A value of the diet may fail of absorption from the intestine Bile salts may be given to aid absorption in such cases, or the new, misnamed "water-soluble vitamin A" may be given by mouth as a supplement The latter is an *emulsion* of very finely divided droplets of vitamin A in water and in this state the vitamin is more rapidly absorbed by healthy persons, infants, or patients with faulty fat absorption than when it is given dissolved in oil [4]

Preformed vitamin A in foods of animal origin is normally very completely absorbed, and both the carotene and vitamin A in butter are likewise nearly 100 per cent absorbed [5] Absorption of the provitamins A (carotenoid pigments) from fibrous vegetable material is much less efficiently accomplished Carotenes in green peas were found to be better utilized than those in spinach[6] but both these vegetables and carrots have much lower vitamin A value, when taken as food, than equivalent quantities of the vitamin itself taken in cod liver oil Other experiments on the relative utilization of carotenes in vegetables showed those in kale to be 67 per cent available, those in sweet potatoes 37 per cent and those in carrots 35 to 40 per cent utilized [7] The degree to which provitamins in vegetable foods are available later as vitamin A in the body will vary not only with the kind of food but also in different individuals and at various times.

It is well to remember that the very high theoretical vitamin A values for some green and yellow vegetables (as listed in tables) may be misleading, due to incomplete absorption and conversion, they may be expected to yield only one-third to one-half as much vitamin A in the body as the listed amount

The presence of *mineral oil* in the intestine interferes with the absorption of vitamin A, carotenes, and other fat-soluble vitamins alike, because they dissolve in this oil, which is nonabsorbable and so excreted in

[4] Lewis, J M, *et al*, Pediatrics, 5, 425 1950
[5] Kreula, M, and Virtanen A I, Upsala Lakareforen Forh, 45, 355, 1939.
[6] Booher and Callison, J Nutr, 18, 459, 1939
[7] Callison, Orent Keiles, *et al*, J Nutr., 37, 139, 1949

the feces[8] Therefore mineral oil should not be incorporated in foods (as in salad dressings) and, if used as a laxative, it should be taken only in moderate amount and at a period remote from mealtimes (e g., just before going to bed at night).

The conversion of provitamins into vitamin A was formerly thought to take place in the liver, but later experiments[9] have shown that probably much of this conversion is accomplished in the intestinal wall during absorption of the provitamins into the lymph, during such absorption, the lymph was found to be higher in vitamin A content than was the blood in the general circulation Both *vitamin A* and *carotene* are *carried in the blood*

The *liver* takes up any excess of these substances from the blood and *stores reserves of this vitamin,* which *can be released into* the blood and carried to the tissues later as needed. The level of vitamin A in the blood is thus kept fairly constant and would not be affected by vitamin A-poor diet until the body reserves were nearly exhausted Nearly 95 per cent of these reserves are in the liver, in rats, the liver was found to be 200 to 400 times richer in vitamin A than muscle tissue, with smaller amounts stored in the kidneys, lungs, and fatty tissues. How much vitamin A has been tucked away in the liver, of course, depends on whether the habitual diet has been rich or poor in vitamin A and its precursors. Body stores of water-soluble vitamins are only sufficient for a few weeks or months, under favorable circumstances, liver stores of vitamin A may be adequate to meet body needs for two or three years. Liver reserves of this vitamin are usually lowest at birth and are built up with advancing years; in diseases of the liver, notably cirrhosis, these stores are markedly reduced

Since reserve stores of vitamin A exist but are variable in amount in different individuals, it is natural that *symptoms due to vitamin A lack should develop rather slowly,* and that the time interval before deficiency symptoms appear will differ according to the extent of the body stores available to draw on in time of need. Irrespective of liver reserves, some persons develop the eye symptoms characteristic of vitamin A lack much more readily than others[10], a *low level of vitamin A in the blood* cannot be shown to occur regularly in cases of poor dark adaptation or night blindness, although it is usually present in xerophthalmia,[11] a disorder which develops after longer periods of vitamin A deficiency. In general there is a rough parallel between levels of vitamin A in the diet and in the blood, but exceptions occur frequently enough to make values for

[illegible] J Nutr 3 345 1931 Dutcher, R A , *et al* , J Nutr , 8, 269, 1934, [illegible] Sta Tech Bull , 84, 375, 1940
[illegible]), 1946, Kon and Thompson, Brit. J. Nutr , 5, 114, 1951

[10] Caveness, Satterfield, and Dann, Arch Ophthalmol , 25, 827, 1941

[11] Sie, B. L., Arch Augenheilk, 110, 610, 1937.

vitamin A in blood an uncertain index of the nutritional status in regard to this vitamin.[12] It has been suggested[13] that following the blood level after administering a single test dose of vitamin A (7,500 units) is more informative as to the true nutritional level, in persons with low liver stores due to vitamin A deficient diets, more of the test dose will be taken up by the liver and the curve of blood vitamin A will be consistently lower than in those whose previous intake of this vitamin has been adequate or liberal.

As previously stated, no vitamin A is *excreted* in the urine (since it is not water-soluble) but considerable unabsorbed carotene is normally found *in the feces.* In disorders where the stools are loose and frequent, or where bile is lacking, most of the carotene and even some of the vitamin A intake may fail of absorption. During lactation, there is a considerable output of vitamin A in the milk secreted, so that the need for extra quantities of this vitamin is probably greater at this time than in pregnancy.

Interrelations in metabolism between vitamin A and other vitamins have been shown to exist. Vitamin A can lose its potency by oxidation, both vitamin E and ascorbic acid (vitamin C) are thought to "spare" vitamin A by acting as antioxidants, substances that enhance the preservation of vitamin A in its biologically active form.

Human Requirement and Standard Allowance

Vitamin A values (both for requirements and in foods) are stated in *International units* (I.U.) rather than by weight. One International unit is defined as equivalent to 0.6 microgram of pure beta-carotene, or to 0.3 microgram of pure vitamin A. This difference is due to the fact that it would take *at least twice* as much beta-carotene as vitamin A to produce the same effect on the body, since cartenes have been shown to be no more than 50 per cent absorbed and converted into vitamin A in the body. In addition to the standard beta-carotene (of known biological potency), the World Health Organization has recently made available crystalline vitamin A acetate as a new reference standard (0.344 micrograms constitutes 1 unit).

It will be evident that the human *requirement* will differ according to whether the major part of the dietary intake is in the form of vitamin A (from animal sources) or of the less efficient precursors of this vitamin supplied in vegetable foods. One study[14] led to the conclusion that 2,500 I.U. of vitamin A or 5,000 I.U. of beta-carotene are sufficient to meet the daily requirement of normal adults. A British committee[15] placed the minimum requirement lower but the amount of carotene re-

[12] Steininger, Roberts, and Brenner, J.A.M.A., 113, 2381, 1939.
[13] Ruch, D. M., *et al.*, Proc. Staff Meet., Mayo Clin., 21, 209, 1946.
[14] Wagner, K. H., Zeit. Physiol. Chem., 264, 163, 1940.
[15] Vitamin A Requirements of Human Adults, Med. Research Council Special Rept. Series 264, London, 1949.

quired to furnish this amount of vitamin A at a higher figure—namely, 1,300 I U. of vitamin A daily as a minimum protective dose for adults, 2,500 I.U. as a recommended allowance, but 7,500 I U. as a daily intake if carotene is the sole source of vitamin A in the diet.

The *standard allowance* should be set considerably above the requirement, in order to allow for incomplete absorption or conversion of carotene to vitamin A and also for a good surplus to build up reserve stores in the body. The allowance that is considered sufficient for the promotion of health will vary according to the standard of health set. Sherman and co-workers found,[16] in long-term feeding experiments on rats, that vitamin A intakes up to four times the quantity required to prevent deficiency symptoms brought returns in health, delayed senility, and longer life; translating this into terms of human requirements, he states *that from 6,000 to 12,000 I U daily for adults would be a scientifically* logical allowance to provide "for the maintenance of such a bodily reserve as has been found to be favorable for higher health and longer life."[17]

The standard allowances recommended by the Food and Nutrition Board, National Research Council (1958), are considerably more moderate and are evidently regarded by them as furnishing a sufficient margin over requirement to safeguard health Their *recommended daily allowances* of vitamin A for adults and young people from 13 to 20 years of age follow.

	I U.
Normal adult	5,000
Pregnancy (second half)	6,000
Lactation	8,000
Boys or girls, 13–20 yrs	5,000

Allowances for *children* should be high per unit of weight, to provide extra vitamin A for growth, but the total is less than for adults (1,500–4,500 I U), increasing with age and weight

As stated in International units, the vitamin A allowances may seem large but *5,000 I U.* would actually be equivalent to only *1.5 mg of* vitamin A. This allowance is based on the assumption that about one-third will be supplied in the form of vitamin A and two-thirds as the precursor, carotene. In the average American diet, surveys show that the distribution is nearer half from foods of animal origin and half from vegetable sources (see Fig 93). Adults who take little whole milk, butter, or eggs (carriers of preformed vitamin A), and depend more heavily on vegetable sources that contain the provitamins, would do well to take amounts even more liberal than the standard allowance Actually on a

16 Batchelder, Am J Physiol, 109, 430, 1934, Campbell, *et al*, J Nutr, 30, 343, 1945, Sherman and Trupp, J Nutr, 37, 467, 1949

17 Sherman, H C, Chemistry of Food and Nutrition, p 468 Macmillan, 8th ed, 1952.

5,000 I U intake, if ⅔ of it is furnished by vegetable sources, one could count on only about 3,330 I U. of the vitamin available to the body, as follows.

Preformed (animal sources)	1,666
As provitamins (vegetable sources) 3,334 I U, with 50% conversion yields	1,667
	3,333

It is not difficult to get this amount, provided foods are wisely chosen However, surveys show that it is not uncommon for the diet to fall below these standards, especially among low-income families A study of diets of high school students from low-income groups in New York City[18] revealed that about 40 per cent of them were getting less than two-thirds of the recommended amounts of vitamin A References to further surveys in other parts of the country are given in the list of suggested reading at the close of the chapter How high the prevalence of vitamin A deficiency is considered will depend on the criteria set for deficiency. In the United States, marked symptoms of deficiency are seldom seen except in undernourished infants and young children, but a good many diets supply less than optimum amounts.

How to Get Daily Quota in Foods

The most important *animal sources* of vitamin A are *liver, butterfat,* and *egg yolk* Milk, cream, ice cream, and whole milk or cream cheeses all carry vitamin A in lesser amounts The vitamin A value of these foods may vary widely according to the vitamin A value of the food of the animals that produced them Livers from older animals and from those that are fed on green fodder contain much larger stores of vitamin A Butterfat in the milk of cows is usually yellower and of higher vitamin

Figure 93 Percentages of vitamin A value contributed by various food groups in the average American diet (Boober, in Wohl, DIETOTHERAPY)

[18] Wiehl, D G, Milbank Memorial Fund Quart, 20, 61, 1942

quired to furnish this amount of vitamin A at a higher figure—namely, 1,300 I U. of vitamin A daily as a minimum protective dose for adults, 2,500 I.U. as a recommended allowance, but 7,500 I.U. as a daily intake if carotene is the sole source of vitamin A in the diet.

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Table 15 Vitamin A Value of Typical Foods*

Food	International units		
	Per 100 grams, raw	*Size average serving*	*Per avg svg*
Liver, beef	43,900	2 slices, fried (74 gm)	39,600
Carrots (deep color)	12,000	⅔ cup, diced, ck (100 gm)	12,000
Green leafy vegetables (4000–15,000), average	7,875	½ cup, cooked (100 gm)	7,875
Sweet potatoes (deep color)	7,700	1 medium-sized, baked (120 gm)	11,410
Apricots, dried	7,430	4 halves, ck., 2 tbsp juice	2,420
Squash, winter	4,950	½ cup, cooked	4,950
Broccoli	3,500	⅔ cup, ck, or 1 large stalk	3,400
Pumpkin	3,400	½ cup, cooked	3,400
Cantaloupe (deep color)	3,420	½ melon, 4½ in diam	5,130
Butter (2000–4000), year-round average	3,300	1 avg pat (10 gm)	330
Margarine, fortified	3,300	1 avg pat (10 gm)	330
Prunes (dried)	1,890	4 medium, ck, 2 tbsp juice	545
Cheese, cream	1,450	1 oz, 2 tbsp	410
Cheese, Am, cheddar	1,400	1 oz, avg svg	400
Lettuce, green leaf	1,620	2 lg or 4–5 sm leaves	810
Eggs, whole	1,140	1 avg sized (54 gm)	550
Tomatoes	1,100	1 medium-sized (150 gm)	1,650
Asparagus, green	1,000	6 stalks, canned (100 gm)	800
Cream, thin (20%)	830	4 tbsp (60 gm)	500
Ice cream, plain, avg	520	⅙th of 1 quart (100 gm)	520
Green vegetables, other than listed above, avg	500	Avg serving (100 gm)	500
Yellow vegetables, other than listed above, avg	330	Avg serving (100 gm)	330
Other vegetables (10–90), avg	50	Avg serving (100 gm)	50
Fruits, fresh:			
Apricots	2,790	2–3 medium	2,790
Nectarines	1,500	2 medium	1,500
Peaches, avg yellow	880	1 medium large	880
Cherries	620	15 large	620
Watermelon	590	1 slice 6 in diam × 1½ in (600 gm)	3,540
Others (tr to 400), avg	135	Avg serving (100 gm)	135
Milk, whole, fresh	160	1 pint	775

* Figures from U. S. Dept Agric Handbook No 8, "Composition of Foods—Raw, Processed, Prepared," 1950

A value when the animals are grazing in green pastures than when stall fed in winter, but improved feeds for dairy cattle (together with ability to draw on stores of vitamin A in the liver) result in less seasonal variations in vitamin A content of milk and butter than were formerly common *The yellowness of egg yolks and butterfat is not an infallible guide* to their vitamin A value, since they contain both the yellow provitamins A and the colorless vitamin A.

Attention should be called to the fact that margarine has been "fortified" by addition of vitamin A (also vitamin D) up to the level found as a year-round average in butter (15,000 I.U. per pound, or 3,300 I U. per 100 grams). This makes it fully acceptable nutritionally as a less expensive substitute for butter

Important *plant sources* of vitamin A value are the *green and yellow vegetables* used as human food, as well as all green plants upon which farm animals feed As the vitamin A value of plants is due entirely to yellow carotenoid pigments, either alone or found in conjunction with chlorophyll, the depth of yellow or green color is a true index of their potential vitamin A value. Most thin green leaves (spinach, kale, turnip greens, etc) have a vitamin A value from 5,000 to 15,000 International units (average about 8,000 I U.) per 100 grams, bleached inner leaves of cabbage and lettuce (as well as bleached asparagus) are of low vitamin A value Carrots may vary in vitamin A value from 2,000 to 12,000 I U per 100 grams, and sweet potatoes also vary widely in vitamin A value (1,500–7,700 I U.), according to the depth of their color. Average vitamin A values of other green and yellow vegetables and yellow fruits are given in Table 15 (p 281).

Grains, sugar, and *vegetable oils* carry little or no vitamin A, while lean muscle meats, nuts, and many common fruits and vegetables provide only minor quantities of this vitamin. The body fat of animals is usually low in vitamin A, but that of fish may contain considerable amounts of this vitamin

Combinations of *foods that will provide the standard daily allowance of vitamin A for an adult* are given below Since the plant provitamins are not so efficiently utilized, it is advisable that foods of animal origin should provide part of the vitamin A in the diet. *Each of the following food combinations will furnish somewhat more than 5,000 I.U.* of vitamin A:

1 pint of milk	3 tbsp butter	[illegible] eggs
½ sweet potato	avg. svg broccoli	4–6 dried apricot halves
2 halves canned peaches	1 banana	6 oz tomato juice

There is danger that the diet will provide less than optimum amounts of vitamin A unless green and yellow vegetables are used frequently, and in addition they are inexpensive sources of the vitamin for low-cost diets. This danger of inadequacy of the diet may be illustrated by the fact that the following group of foods, which might seem to con-

VITAMIN D

Cod liver oil had long been established as an excellent preventive for the disease called rickets before the reason for its potency in this respect was accounted for by science In 1921, McCollum and coworkers found that, *after destruction (by oxidation)* of all the vitamin A in cod liver oil, it still retained its rickets-preventing potency This indicated the existence of a second fat-soluble vitamin, carried in liver oils and certain other fats, which was called the ***antirachitic vitamin*** or ***vitamin D.*** Later work showed that there are at least ten substances which exert vitamin D-like activity in varying degrees, but only two of these are of practical importance (D_2 and D_3) Since all of them are closely related chemically and produce a like effect on the body, the term vitamin D is often used collectively to indicate the *group* of substances that show this vitamin activity

Vitamins D_2 and D_3, and Their Precursors

Steenbock and Hess discovered independently that when certain foods were exposed to ultraviolet light their ability to protect animals against rickets was increased This meant that some foods must contain precursors of vitamin D, substances which are altered chemically by light of certain wave-lengths so that they become able to function as vitamins in the body We now know that the *provitamin D* in plants differs from the animal precursor, and that each gives rise to a slightly different vitamin D when activated by light In plants, a substance known as *ergosterol* is converted by light into vitamin D_2, in animals, a derivative of *cholesterol* is the precursor of vitamin D_3 Apparently birds respond better to vitamin D_3, but most animals can utilize either type of vitamin D Vitamin D_3 occurs in fish liver oils and foods of animal origin, such as eggs, butter, milk, and cream Vitamin D_2 has been prepared in concentrated form by "irradiation" of yeast, and is sold as pure crystals under the name of *calciferol* and in solution in neutral oil as *viosterol* Vitamin D_2 is also known by the chemical name of ergocalciferol, while D_3, which is formed from the cholesterol derivative, is called cholecalciferol

The vitamins D belong to the class of organic substances known as *sterols,* compounds with large molecules containing an "alcohol group" and with the same solubilities as fats They are very stable compounds, resisting destruction by heat and oxidation, as well as by acids and alkalis Obviously they are sensitive to light, especially that of shorter wave-lengths (ultraviolet)

Vitamin D is measured in terms of International units Crystalline vitamin D_3 is now available and in 1949 was adopted as the standard reference material, one unit corresponds to the vitamin activity of 0 025 *microgram* of this pure substance The U S Pharmacopeia (U.S P) unit,

stitute the basis of a "good" diet, falls considerably short of the 5,000 I U. daily vitamin A allowance.

1 pint of milk 3 squares butter 1 egg 8 oz orange juice 1 avg svg fresh fruit 3 avg svgs vegetables, *not green or yellow*	furnish approximately 3,000 I U. of vitamin A

If one of the vegetables served were of the green or yellow variety, the vitamin A value of this diet would be raised decidedly, usually up to the 5,000 I U level or more, provided the vegetable chosen is strongly colored and an average-sized serving (100 gm) is eaten.

Since vitamin A and its precursors (the carotenes) are insoluble in water and stable to heat at ordinary cooking temperatures, *foods lose little of their vitamin A value in cooking or canning* Drying of eggs, vegetables or fruits, with exposure to air, sunlight, or high temperatures, may cause serious loss of vitamin A value Evaporation, pasteurization, or irradiation of milk has little or no effect on its vitamin A content. Vegetables should be stored at low temperatures to conserve their vitamin A value and, of course, quick freezing is an excellent means to this end Animal fats should be kept in a cold dark place, and fish liver oils should be protected from light by being put in a dark glass bottle.

Fish liver oils, the richest source of vitamin A, vary in vitamin content with the species of fish. The U.S P. standard for cod liver oil calls for not less than 850 I U *per gram*, so that it has at least twice the vitamin A content of beef liver, the richest common food source. One to two teaspoonfuls of cod liver oil (varying with its potency) will provide the full daily allowance, all in the form of the readily assimilable preformed vitamin A Liver oil from halibut has a much higher content of vitamin A than cod liver oil, and those from sword fish and shark are higher still Capsules of liver oil concentrates (dissolved in neutral oil) usually contain the daily adult allowance, 5,000 I.U , but may be obtained for therapeutic use in high potency (up to 50,000 I.U or more per capsule)

Attention should be called to the fact that long-continued large doses of vitamin A have a *toxic* effect and regular moderate intake (5,000 to 10,000 I U per day) has been shown to be better for building up stores in the liver Toxic symptoms (hypervitaminosis A) occur most often in children one to three years of age, after they have received 75,000 I U or more of vitamin A daily for at least six months, such symptoms, which include excessive irritability, swellings over the long bones, dry and itching skin, are relieved by discontinuing the dosages of supplementary vitamin A. In adults the early symptoms of toxicity are headache, nausea, and diarrhea, a *great excess of vitamin A may also lead to* decalcification of bones.

especially with so-called "sunlight lamps" whose light contains more of the potent ultraviolet rays than does natural sunlight

The lower animals also generate vitamin D in their bodies on exposure to light Steenbock kept chicks indoors on a vitamin D-poor ration, conditions which led to stunted growth and leg weakness, exposure to sunlight for a half hour daily served to protect the chicks against these effects of vitamin D lack Hens and cows, when allowed outdoor life in sunny regions, produce eggs and milk of higher vitamin D content Because vitamin D is the *only* vitamin that can be formed in the animal body by means of light, it is sometimes referred to as "the sunshine vitamin"

Effects of Vitamin D Deficiency

The effects of a lack of vitamin D, as seen most strikingly in young animals, are failure to make proper *growth*, lack of normal development of the *bones*, and a tendency to increased susceptibility to infections

Rickets is a bone disease that occurs in children (usually under three years of age) and young animals, and it is generally closely associated with *lack of vitamin D*, although this is not the only factor involved The metabolism of calcium and phosphorus is disturbed in such a way that the deposition in the bones of the inorganic salt (calcium phosphate), which is responsible for bone rigidity, cannot proceed normally Hence this disease is characterized by weak bones, which readily develop curvatures when compelled to carry the weight of the body, and by overgrowth of the softer tissues (cartilage) at the ends of the bones Rachitic deformities develop, such as *bow legs, knock knees, enlargement of* bones about the *joints*, and a *narrow, distorted chest* with "beading" of the ribs These deformities, not themselves causing death, may persist into adult life, when the shrunken chest may predispose to lung diseases,

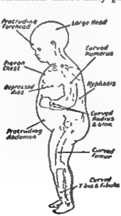


Figure 95 Diagram showing deformities that are symptoms of severe cases of rickets (Harris, VITAMINS IN THEORY AND PRACTICE, Macmillan Co)

Figure 94 Effect of exposure to sunlight in stimulating growth Both chicks received the same ration, which was poor in vitamin D, but the one on the right was exposed to sunlight one-half hour daily, thus permitting generation of the needed vitamin D in its body (Courtesy of Dr H. Steenbock, University of Wisconsin)

often used for potency of medicinal preparations, is the same as the International unit (as was also true for vitamin A).

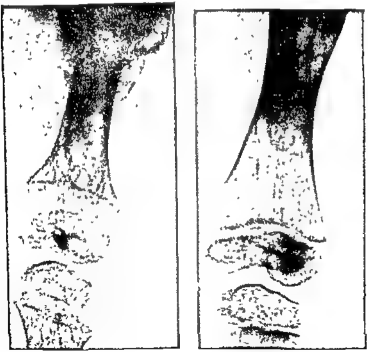
Formation of Vitamin D in the Body by Sunlight

Provitamin D_3 is present in the oily lubricating material in the skin and on its surface Hence it is not surprising that, when *sunlight*, in which there is light of short wave-lengths (ultraviolet light), falls directly on the skin, some of the provitamins will be converted into vitamin D_3 The vitamin thus formed in or on the skin is readily taken into the local circulation and carried by the blood to all parts of the body. Excess formed over immediate body needs can be stored in considerable amounts in the liver and may be found also in the fatty tissues, lungs, spleen, and brain.

Hess found that rickets could be prevented or cured by exposing children (without clothing) to sunlight or the rays of an *ultraviolet lamp*, since they thus were enabled to manufacture vitamin D in their own bodies. Overexposure to ultraviolet rays causes sunburn and a toxic condition in the body, so that the time of exposure should be brief,

changes in activity of certain ductless glands. Although this disorder is *seldom seen in the United States, it is common among women in the* Orient, the Middle East, and North Africa (Mohammedan areas) as the result of inadequate diet, frequent child-bearing, and lack of sunlight (they are confined indoors in the custom of "purdah").

It should be obvious that *rickets* may also be caused by *lack of either calcium or phosphorus,* since these are the building materials for the calcium phosphate upon which the rigidity and strength of bone depends. No amount of vitamin D will serve to promote normal bone development unless the mineral elements necessary for building strong bones are provided in the diet in adequate quantities. Conversely, rickets may develop on diets that supply plenty of calcium and phosphorus (e.g., in infants on milk diet) if *vitamin D is lacking.* The vitamin D may be supplied in food or fish liver oil, or it may be generated in the body by exposure to sunlight, or some may be obtained from each source. A diet rich in one of the necessary mineral elements and poor in the other



A B

Figure 97. X-ray pictures of same joint in a 10-year-old Mexican boy, before

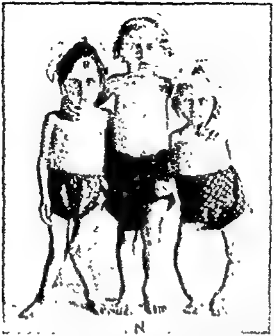


Figure [illegible] Stunted growth and bone deformities in rachitic children. The two children with rickets are the same age (6 years) as the normal child in the center (Picture taken by British Medical Mission in Vienna after World War I)

often fatal (especially pneumonia), and a narrow pelvis may make child-bearing difficult for women Rachitic children are often irritable and nervous (or listless and disinclined to play), pigeon-breasted, pot-bellied, and have peculiar shaped heads, in addition to having deformities of arm and leg bones Milder cases of rickets, associated with less severe lack of vitamin D, may be detectable only by blood analyses (either the serum calcium or phosphate, or both, are below normal levels), by failure of bones to grow properly in length, and by x-ray pictures which show the characteristic failure of normal deposition of calcium phosphate in the ends of the bones When "healing" takes place (usually as a result of giving vitamin D), new deposits of calcium phosphate are laid down in the cartilage along the line of demarkation between the smaller bone (epiphysis or *head*) and the main part or *shaft* of the long bone. This increase of mineral deposit near the ends of the bones is indicated by increased density in x-ray pictures (see Fig. 97, B).

Osteomalacia is a softening or weakness of bone that occurs in adults, especially during pregnancy or in old age, due to the fact that the bones have been robbed of part of the mineral deposits made in earlier years. Such depletion of bone stores of calcium and phosphorus may be caused either by poor utilization of these mineral elements associated with vitamin D lack, by an insufficient supply of calcium or phosphorus in the diet to meet body needs, or possibly in old age by

in the body to an important extent It can be passed from the mother's body to build up stores in the child before birth, or into breast milk on which the infant feeds, and in both these ways it may help to protect the infant against the development of rickets It is noticeable that the age at which rickets is most likely to develop (1 to 3 years) coincides with a period of rapid growth (high need) and one in which there has been little chance to accumulate large body stores of vitamin D The gradual accumulation of such stores with age doubtless accounts in large part for the infrequency of any evidences of vitamin D deficiency in adults

The chief *functions* of vitamin D are to promote *growth* and proper *mineralization of the bones and teeth* Jeans and Stearns[19] made extensive studies of the effect of different levels of vitamin D intake upon infants, they found that 135 I U daily would prevent rickets but 300 to 400 I U daily resulted in more rapid growth (especially in length) and earlier eruption of teeth Sherman and Stiebeling,[20] with laboratory animals, also found improved rates of growth and development at higher levels of vitamin D intake Mellanby[21] early noted the effects of lack of both vitamins A and D upon the formation and quality of the teeth in animals, while others[22] have found higher levels of vitamin D (800 I U) for children prevented the increase of tooth decay that ordinarily occurred in late winter or early spring The intimate relationship between this vitamin and the normal deposition of calcium phosphate in the bones should be evident from the discussion (pp 285–287) of the bone symptoms produced by its lack in the rachitic child

The exact method by which vitamin D brings about its effects has been subject to much investigation and is not yet entirely clear There is general agreement that the main result of its action is the *improvement of utilization of calcium and phosphorus* supplied in the food It seems to increase the absorption of calcium (and secondarily also of phosphorus) from the "gut," probably by increased permeability of the intestinal wall to calcium, this helps to keep the content of these two elements in the blood up to levels that are favorable for deposition of calcium phosphate in the bones (the level of either or both of these elements in blood serum is depressed in rickets) Nicolaysen[23] found that the extent of calcification of bones seemed to be determined solely by the amount of calcium and phosphorus brought to them by the blood, although the "architecture" of bones (crystalline structure on which their strength depends) is influenced by vitamin D Others believe that vitamin D exerts some sort of local controlling action over the process of calcification at the ends of growing bones and in the healing of bone

[19] Jeans, P C , and Stearns, G J Pediatrics, 13, 730, and J A M A , 111, 703, 1938
[20] Sherman, H C , and Stiebeling, H K , J Biol Chem , 83, 497, 1929
[21] Mellanby, M , "Diet and the Teeth," Medical Research Council, Spec Rept Series , Nos 140, 153, 191, London, 1929, 1930, and 1934
[22] McBeath, E C , and Zucker, T F , J Nutr , 15, 547, 1938
[23] Biochem J , 31, 1937, several papers, and Acta Pediat , 23, 405, 1939

predisposes toward development of rickets. The best *protection* against this disease and the most favorable bone growth is secured when calcium and phosphorus are supplied in approximately equal amounts (as in milk) and liberal quantities of vitamin D are available.

Rickets formerly was a common disease among young children, so prevalent among children of the poor who lived in dark tenements in cities that it became known as "the disease of poverty and darkness." Under these conditions, both poor diet and lack of sunlight contributed *to its development. Negro children in cities are especially susceptible* to this disease, since the pigment in their skins prevents the short rays of *sunlight from passing through to form* vitamin D *in* their bodies. In tropical or semi-tropical regions and with country children, exposure to sunlight often protects against rickets even when the mineral content of the diet is not above reproach. In arctic regions, with long winter darkness, the children are protected from rickets because they eat fish fat and livers, foods very rich in vitamin D.

Since the importance of vitamin D has been appreciated and the practice of giving cod liver oil or vitamin D concentrates (such as viosterol) to young children has become widespread, severe cases of rickets are seldom seen in the United States, although mild rickets is still of fairly common occurrence This is well illustrated by statistics of preschool children in Chicago, from 1926 to 1932, examination showed 16–21 per cent with definite evidence of rickets, but by 1935 the percentage fell to 7 per cent with only 0 03 per cent of cases of severe rickets The incidence of severe rickets, on the basis of these 1935 figures, had been reduced to three cases per ten thousand children It is clear that rickets as a "disease" is well on the way to being eradicated in this country, but doubtless very many children do not achieve full growth and proper development of bones and teeth because of lack of "optimum" amounts of calcium, phosphorus, or vitamin D.

Vitamin D in the Body, and Its Functions

Vitamin D, being a fat-soluble factor, is absorbed from the intestine along with fats Bile aids in this process, and conditions unfavorable to fat absorption (lack of bile, disorders like sprue and celiac disease, etc) mean poor utilization of vitamin D from foods or fish liver oils For very young *infants, especially premature babies, in whom ability to* utilize fats is not yet developed, an emulsion of finely divided particles of the vitamin in water (so-called "water-soluble" vitamin D) is recommended instead of the preparation dissolved in oil Premature infants have an *extra* high need for vitamin D, because of rapid growth and the fact that they have been deprived of the body stores of calcium and phosphorus ordinarily received through the mother in the last few months of pregnancy.

In common with other fat-soluble vitamins, vitamin D can be stored

min D through its functioning in an enzyme or coenzyme, a mode of functioning established for many of the B complex vitamins but not yet for the fat-soluble vitamins

Whatever the mechanism by which this vitamin exerts its influence, there is no doubt that it promotes better utilization of mineral elements, especially of calcium and phosphorus Both Jeans and Stearns and Macy and co-workers have shown in extensive balance studies on humans of all ages (infants to adults) that the amounts of calcium and phosphorus retained in the body are increased when *adequate* vitamin D is supplied With infants, Jeans and Stearns found 300 to 400 I U of vitamin D promoted normal growth but 1,500 or more units daily caused loss of appetite and retarded growth Thus amounts in excess of those needed for optimum calcium and phosphorus retention not only produce no further benefits but may do harm Older children varied considerably in the efficiency with which they utilized the calcium of the diet, if the original calcium utilization was poor, the giving of additional vitamin D had much more effect in raising calcium retention than when the utilization of this element was already fairly good The influence of vitamin D in enabling the body to make more efficient use of dietary calcium and phosphorus persists into adult life It should be emphasized that adequate supplies of vitamin D do not in any way decrease the requirements for calcium and phosphorus, the intake of these two mineral elements must always be liberal in order to secure good growth and calcification of bones and teeth

Human Requirements

It is impossible to state the vitamin D requirements exactly We can estimate fairly well the amount of it supplied in foods, but there is no way of knowing how much extra vitamin D is made in the body under the influence of sunlight Since its action is chiefly concerned with the metabolism of bones, which are hidden and relatively inactive tissues, it is difficult to tell whether an adult is or is not getting enough of this vitamin to keep the body in best condition With *young children*, when rapid growth and calcification of bones should be taking place, the need for vitamin D is relatively greater and a deficiency of it will be evidenced by slower growth, and possibly by weak or malformed bones Hence it is easier to gauge the vitamin D requirements of infants and young children

Extensive studies on prevention of rickets enable us to say that 135 I U daily of vitamin D_3 (the "animal form") will usually protect infants from rickets, provided their diet includes a quart of milk each day (to supply calcium and phosphorus in plentiful, readily assimilable amounts)[27] Most pediatricians find that either form of the vitamin (D_2

[27] Jeans, P C, and Stearns, G, J A M A, 111, 703, 1938, also Jeans, P. C, "Vitamin D," J A M A, 143, 177, 1950

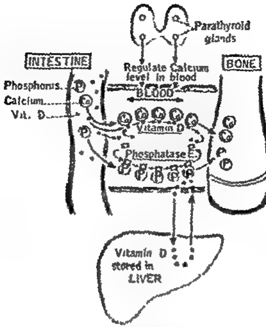


Figure 98 Diagram indicating how vitamin D may function in the body by increasing the absorption of calcium and phosphorus from the intestine, thus raising their level in the blood and promoting their deposition in bone Reserves of vitamin D stored in the liver can be drawn upon to keep up the level of this vitamin in blood and tissues during periods of low intake or extra need

fractures Schneider and Steenbock[24] have offered evidence that vitamin D plays a specific role which favors the deposition of calcium phosphate in the cartilage of developing bone ends at the expense of phosphorus used normally for growth of muscle tissues, the competition of both bones and muscles for phosphorus in the rapidly growing young animal is supposed to be a contributing factor in causing "low phosphorus" rickets. Albright and Reifenstein[25] offer the explanation that the higher level of serum calcium, induced by better absorption of this element, depresses the activity of the parathyroid glands, resulting in reduction of the urinary excretion of phosphorus and hence a "net" increase in the amounts retained in the body Zetterstrom[26] has reported that vitamin D, combined with phosphoric acid, activates phosphatases (enzymes that split off inorganic phosphate groups from organic compounds) found in the intestinal wall, growing ends of bones, and kidney, thus functioning in the absorption, deposition, and retention of phosphate. If this last observation should be confirmed, it would explain the activity of vita-

[24] Schneider, H, and Steenbock, H, J. Biol Chem, 128, 159, 1939
[25] Albright, F, and Reifenstein, E C, The Parathyroid Glands and Metabolic Bone Disease Williams & Wilkins, 1948
[26] Zetterstrom, R, and Ljunggren, M, Acta chem. Scandinav, 5, 283, 1951, also Zetterstrom, R, Nature, 167, 409, 1951.

need for supplemental vitamin D by vigorous adults leading a normal life seems to be minimum For persons working at night and for nuns and others whose habits shield them from the sunlight, as well as for elderly persons, the ingestion of small amounts of vitamin D is desirable" This means that most normal adults get enough of this vitamin, either in their food or by exposure to sunlight, to meet at least their minimum needs

However, during pregnancy and lactation supplemental vitamin D (400 I U daily) is recommended. A liberal supply at these periods is undoubtedly wise since, even though transmission to the fetus and milk is relatively low, the stores of vitamin D in the baby's body and the vitamin D content of milk are appreciably increased by vitamin D in the diet of the mother. In addition, optimum amounts of this vitamin will promote the most efficient utilization by the mother of the calcium and phosphorus in her diet

The amount of vitamin D that will be made in the body through exposure to sunlight will vary according to the *season*, the *locality* in which one lives, and one's life *habits* In the tropics bright sunlight is available the year round, but in most other parts of the world sunlight is scarce during the winter months Sunlight also is richer in untraviolet rays in summer, and more of these rays get through to the "consumer" when the sun is directly overhead, i e, between 10 A M and 2 P M On cloudy or foggy days and in cities covered by smoke pall, almost all of the ultraviolet rays are screened out before light penetrates to the people Window glass and layers of clothing also effectively prevent ultraviolet rays from reaching the skin As only the ultraviolet rays (light of short wave-length and high frequency) have the ability to bring about the chemical change by which vitamin D is formed, persons who live in cities can place little dependence upon making this vitamin in their own bodies, especially in winter Others who live and work outdoors in sunny regions will manufacture considerable vitamin D with the aid of sunlight, and hence will be less dependent on food for it

Vitamin D in Foods

Nature's plan seems to have been that man should generate most of his supply of this vitamin by sunlight, for it is contained more sparsely in foods than is any other well known vitamin In vegetable foods, it is present not at all or only in traces, it occurs, along with other fat-soluble vitamins, in such foods of animal origin as egg yolk, butter fat, fatty fishes, and of course in liver, since this is the storage organ for it The amounts found in these foods are small and vary widely according to the diet of the animal and the extent to which it has been exposed to sunlight As vitamin D is stable to heat and insoluble in water, there is little loss of this vitamin in the cooking or processing of foods

Table 16 lists some typical food sources of vitamin D, with the

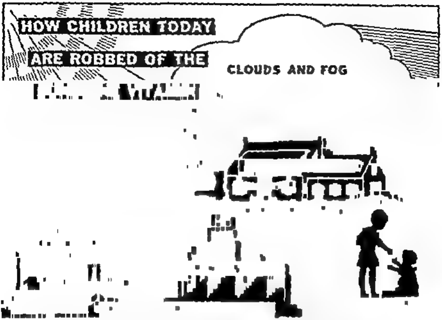


Figure 99 People in country districts and in the tropics can make vitamin D in their bodies through the agency of direct sunlight This drawing shows some of the factors of modern life which screen out ultraviolet light and prevent people from exposure to sunlight, thus robbing them of the chance of making this vitamin in their bodies (Courtesy of the Wisconsin Alumni Research Foundation.)

or D_2) is effective, although when taken in fish liver oils (D_3) there is the advantage that these also carry liberal amounts of vitamin A (not present in viosterol) A daily intake of 300 to 400 I U seems to be needed to support a rate of growth and development "nearer the top of the normal range," while 300-600 I.U daily show a maximum effect on the linear growth (length) of infants.[28]

Less is known about the vitamin D requirements of older children than of infants Jeans and Stearns showed that 300 to 400 I.U. daily, in the form of cod liver oil, favored calcium retention in children from 1 to 12 years of age. They state that in adolescence the need for this vitamin becomes "as universal and as great as in infancy" Johnston[29] believes that in the period of rapid growth just before puberty the need for vitamin D is probably twice as great as at any other time of life, except perhaps during the middle of the first year. The National Research Council's Food and Nutrition Board (1958) recommends 400 I.U of vitamin D daily for children from birth to 20 years of age

The same board (in notes accompanying its recommendations) makes the following statement as to vitamin D needs of adults: "The

[28] Slyker, F, *et al*, Proc Soc Soc Exp Biol & Med, 37, 499, 1937, Stearns, Jeans, and Vandecar, J. Pediat, 8, 1, 1936, Jeans and Stearns, J. Pediat, 13, 730, 1938, Spiedel and Stearns, J Pediat, 17, 506, 1940
[29] Johnston, J A, J.A.M.A, 137, 1587, 1948.

with this vitamin as the easiest way to make certain that everyone gets enough of it. Milk is the chief food that has thus far been enriched as to vitamin D This has been done in three ways—by irradiation of the milk, by addition of a standard amount of a tasteless concentrate from fish liver oil or of viosterol, or by feeding irradiated yeast to cows Most so-called *vitamin D milk* is now made by addition of a concentrate or of a pure preparation of the vitamin, while evaporated and dried milks also have increased vitamin D content The concentration of vitamin D is adjusted so that one quart of the fresh milk, or of the processed milk after the directed dilution, will supply 400 I U, and along with this it will also provide the calcium and phosphorus needed to build strong bones A few special cereals, chiefly for infant feeding, have been enriched with this vitamin in amounts so that an average serving will provide 400 I U, but this extra supply of the vitamin is usually not needed. Obviously when vitamin D milk is used in amount of one quart daily, no other source of the vitamin is required, giving another rich source (such as fish liver oil or viosterol) is superfluous and may even be dangerous

Toxicity

Enough is better than too much as far as vitamin D is concerned, and *mothers should be warned of this fact in case they are giving high* potency vitamin D preparations (e g, viosterol) to their children Single large doses may be given without harm and some pediatricians recommend this method when parents cannot be relied upon to administer the daily dosage, a single dose of 300,000 I U by mouth will be stored in sufficient amounts to protect a child, without exposure to sunlight, from rickets for six months Smaller overdoses, if taken daily, are likely to produce undesirable effects There is some evidence that infants who receive 1,800 I U daily will not grow so well as those who get a more moderate dose With daily doses of 20,000 to 40,000 I U. for infants, or 75,000 to 100,000 I U for adults, serious toxic symptoms may develop, these include vomiting, diarrhea, weakness, loss of weight, and kidney damage The serum calcium is elevated to such a degree that deposits of calcium salts may be found in various organs Adults should be cautioned against the massive doses of this vitamin sometimes given for arthritis and other diseased conditions over long periods, and even moderate overdosage with vitamin D is not good for the elderly. With water-soluble vitamins, overdosage is wasteful but not harmful because the excess is excreted in the urine, with fat-soluble vitamins, the excess remains in the body in such quantities that, in the case of vitamin D and to a lesser extent with vitamin A, it may give rise to toxic conditions Concentrated preparations of any of the fat-soluble vitamins should be used with caution and only under direction of a physician.

Table 16. Vitamin D Content of Typical Foods

Food	*Size of serving*	*Avg Vitamin D, I U*
Fatty fish		
Herring	1 small fish (100 gm)	1,200
Salmon, canned	½ cup drained solids	375–600
Tuna, canned	⅝ cup solids (100 gm)	250
Eggs	1 medium-sized egg	27
Butter	1 oz or 3 avg pats (30 gm)	12
Liver, raw	2 lg slices (100 gm)	15–45
Cream, light to heavy	1 oz or 2 tbsp	4–8
Milk, whole, fresh	1 pint	10

amount that may be counted on from an average serving (although the content in egg yolk and butter will be higher if some rich source of vitamin D has been incorporated in the animals' feed, as is a fairly common practice now) Eggs and dairy products are the only common foods that furnish vitamin D in appreciable quantities, liver and fatty fish are good sources, but are infrequently used. If the daily diet contains 1 egg, 3 tablespoons of butter, and a pint of milk, one could count on getting only about 50 I U of this vitamin from natural foods However, most adults seem to get along at least fairly well on the small amounts furnished in foods, supplemented with the amounts they generate under the influence of sunlight

Enriched Foods and Other Rich Sources of Vitamin D

Those whose daily vitamin D allowance is set at 400 I U. cannot hope to get this much in foods and will need to be given some rich source of the vitamin, this includes children from birth to 20 years and pregnant and lactating women Cod liver oil is the time-honored supplementary source of this vitamin for children Standard cod liver oil supplies no less than 85 I U. per gram (some oils are twice as high), so that one teaspoonful will provide at least 300 I U , and 1 to 2 teaspoonfuls daily are recommended for young children and pregnant women Other fish liver oils (such as those from shark or blue fin tuna) are much richer in vitamin D than is cod liver oil, *concentrates* made from such oils may be taken in capsules, which may carry up to 1,000 I.U per capsule (although 400 I U is enough to promote maximum utilization of calcium and phosphorus) *Viosterol* is preferred by some because it is tasteless and easy to measure dosage, it carries at least 10,000 I.U of vitamin D per gram, dissolved in neutral oil, and only a *few drops* of it are needed daily.

Since it became known that the low natural vitamin D content of foods could be increased by "irradiation" with ultraviolet light, nutritionists have favored the enriching or "fortification" of a few staple foods

man[31] claim that it activates a reducing enzyme present in the cytochrome of cells, if this is confirmed, it would attribute an essential enzymatic function to this vitamin.

Wheat germ oil is the richest source of this vitamin but it is found also in corn oil and other vegetable oils and in many foods (whole grains, leafy vegetables, liver, meat fats, eggs, butter and milk), so that there is little chance of shortage of it in normal diets

VITAMIN K

This vitamin was discovered in 1935 by Dam of Copenhagen, who designated it by the letter K to stand for "koagulation" (the Danish spelling of the word) Its function is to assist in the formation in the liver of an enzyme called *prothrombin*, which is necessary for the coagulation or *clotting of blood*. In chicks deprived of this vitamin, there are hemorrhages under the skin, often serious internal bleeding, and delayed clotting time of the blood Doses of vitamin K restore blood-clotting time to normal, and thus prevent loss of blood by hemorrhages

This vitamin is found abundantly in green leaves (spinach, kale, alfalfa, etc) and is probably supplied in adequate amounts in the human dietary However, since it is fat-soluble the presence of bile in the intestine is necessary for its satisfactory absorption from the food, too little of it may be absorbed to meet the body needs if the normal flow of bile from liver to intestine is obstructed for any reason Hence patients with diseases of the biliary tract (such as obstructive jaundice)

[31] Nason, A, and Lehman, I R, "Tocopherol as an Activator of Cytochrome c Reductase," Science, 122, 19, 1955

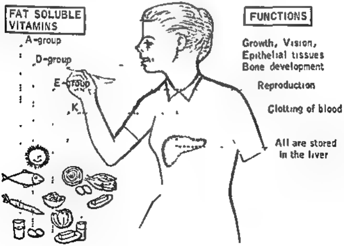


Figure 100

Two *other fat-soluble vitamins* are known which are of considerable scientific interest. Both are soluble in fat solvents and are stable to heat, but lose their vitamin activity on oxidation. A brief description of these two vitamins will suffice for our purposes because (1) their relation to nutrition has not yet been as clearly established for man as for other animals, and (2) their distribution in foods is such that there is little likelihood of deficiency in the normal human dietary.

VITAMIN E

Vitamin E has been known since 1922 to be an essential factor for *reproduction*, although our knowledge of its effects has been obtained almost exclusively by experiments on lower animals It occurs naturally in four forms (known as alpha-, beta-, gamma-, and delta-tocopherol), all of which have been synthesized, but we still refer to this group of substances with similar vitamin activity as vitamin E. They belong to the class of organic compounds known as sterols (higher alcohols) and one of their most prominent properties is that, by taking up oxygen themselves, they protect certain other compounds such as vitamin A, carotenes, and unsaturated fatty acids from oxidation. They are the chief antioxidants in natural fats and oils and act to prevent fats from becoming rancid; recently they have been added to certain foods to "stabilize" or prevent loss by oxidation of valuable nutrients

A state of vitamin E deficiency has not yet been established in man In rats which have been deprived of vitamin E, the males become permanently sterile and pregnant females are unable to carry young to term, since lack of this vitamin results in death and reabsorption of the embryos in the uterus. Fertility of female rats is not destroyed and, when given sufficient vitamin E later, they give birth to normal litters. Young rats (and other animals) after several months on vitamin E-deficient diets *fail to grow normally* and also develop *weakness and degeneration of the skeletal muscles*, a condition known as *muscular dystrophy*, lesions have also been found in heart muscle Although administration of vitamin E will prevent or cure these deficiency symptoms in the lower animals, it has usually failed to benefit human beings when given to prevent repeated abortions, or for the cure of muscular dystrophy or weakness of heart muscles No therapeutic uses for it for man have yet been clearly demonstrated

Vitamin E has been shown to protect both vitamin A and carotene from destruction by oxidation, especially in the alimentary tract. In this way, vitamin E exerts a sparing action and "stretches" the supply of vitamin A available to the body,[30] which may be of importance if the intake of vitamin A is barely adequate for body needs Vitamin E may also exert a specific influence on oxidations in body tissues. Nason and Leh-

[30] Hickman, K. C, *et al*, J Biol Chem, 152, 303, 313, and 321, 1944.

sary for good absorption from intestine, path or paths of excretion, ability to be stored in the body.

2. Name four fat-soluble vitamins and give for each one its chief use (or uses) in the body, and the effects of moderate and severe lack of it in the diet. How does its function in nutrition account for the type of symptoms that result from an insufficient supply?

3 What is meant by provitamins or vitamin precursors? Name the precursors of vitamin A and tell in what classes of foods they are found How and to what extent are they made into vitamin A in the body? What foods contain both the provitamins A and vitamin A? Which contain only preformed vitamin A? What determines whether the vitamin A value of eggs, milk, and butter is high or low? Is the depth of color of egg yolk and milk fat a reliable index of their vitamin A value, and why? Does the depth of color of green and yellow vegetables indicate their relative vitamin A value, and why?

4 List ten vegetables and three fruits of high vitamin A value, list the five foods of animal origin that are the richest sources of vitamin A (consult Table 15, p 281), and tables in the Appendix for vitamin A values of individual foods)

5 Plan a diet that will furnish 2,500 International units of vitamin A, modify this diet so that it will provide 5,000 I U vitamin A, substitute foods or add some rich sources of vitamin A, so that the diet as modified will supply 10,000 I U (or more) of vitamin A Is it difficult to get as much as 5,000 I.U (recommended daily allowance for adults) in the diet? What will happen if the diet supplies 2,500 I U. one day and 10,000 I.U the next day? Of what advantage is it to have an intake of vitamin A considerably in excess of the minimum requirement?

6 What are the precursors of vitamin D and where are they found? By what means are they transformed into vitamin D? Under what circumstances can this vitamin be made in the body? Under what conditions will persons make little of this vitamin in their bodies and so be dependent almost entirely on food sources for their supply of vitamin D? What foods carry small and variable amounts of vitamin D? How may the natural low content of vitamin D in foods be increased? What foods have been reinforced as to their vitamin D content?

7. At what periods of life is the need for vitamins A and D relatively high, and why? What rich source (or sources) of these vitamins is usually given at these periods to insure a plentiful supply of vitamins A and D? Why will a baby that is breast fed derive more benefit if supplementary vitamins A and D are given to it directly than if they are given to its mother?

8 How may incipient rickets be detected? How can rickets be prevented? How can it be cured?

9 What are the earliest symptoms of vitamin A lack? What course would you recommend for getting rid of such symptoms?

are likely to suffer from deficiency of vitamin K (even though there is plenty of it in the diet), which is manifested by *inability of the blood to clot promptly* Injuries or surgical operations in such persons may result in dangerous hemorrhages Doses of vitamin K, given along with bile salts, have proved effective in raising the level of prothrombin in the blood and thus restoring the normal clotting ability of the blood Similarly, newborn infants sometimes suffer from severe hemorrhages, and it is known that there is normally a low level of prothrombin in the blood at birth For this reason physicians now favor the routine administration of vitamin K either to the mother before delivery or to the infant at birth, as a precautionary measure.

Concentrated preparations of vitamin K have been made either from alfalfa or from putrified fish livers, in which it has been formed by action of bacteria. Both naturally occurring forms of the vitamin (K_1 and K_2) have been synthesized, as well as chemically related substances that possess some degree of vitamin K activity. One such substance synthesized by chemists is *menadione*, which has largely replaced the natural vitamins K for therapeutic uses, it is more effective than the natural vitamins in inducing blood coagulation, so that smaller doses are required (large doses are slightly toxic). Menadione is fat-soluble but several of its derivatives are soluble in water and can hence be given intravenously

The site of prothrombin formation is the liver, so that injury to the liver (as in various liver diseases) is likely to result in a low level of prothrombin in the blood and delayed clotting time If the damage to liver tissues is severe, administration of vitamin K will not be effective in raising blood prothrombin and restoring clotting time to normal. Apparently only small amounts of vitamin K are stored in the liver

Food sources of vitamin K include all of the green leafy vegetables, egg yolk, soybean oil, and liver This vitamin is also formed by bacteria in the intestine, perhaps from precursors in the food. In experimental animals, the administration of sulfa drugs, which reduce the numbers of bacteria in the intestines, resulted in vitamin K deficiency as evidenced by lower levels of prothrombin in the blood[12] Vitamin K deficiency in man seldom, if ever, results from lack of this vitamin in the diet (or provided by action of intestinal bacteria), but arises from abnormal conditions that interfere with its absorption and utilization

QUESTIONS AND PROBLEMS

1. Tell how fat-soluble vitamins differ from water-soluble ones in each of the following respects. solubilities, types of food in which they are carried, losses in cooking and processing of foods, conditions neces-

[12] Black, Elvehjem, *et al*, J Biol Chem, 145, 137, 1942, Kornberg, Daft, and Sebrell, *ibid*, 155, 193, 1944

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into bread, which is often leavened by yeast. Bread has thus been for centuries literally "the staff of life" of many nations, especially of those of Europe and America.

The principal grains are *rice, wheat, rye, barley, oats,* and *corn* Rice, grown in moist tropical or semitropical climates, has the largest consumption of any of the grains because of its very important place in the diet of the populous eastern countries Wheat comes next in total amount produced and consumed, largely due to the fact that its higher gluten (protein) content makes it the preferred grain for making yeast breads Rye is grown in northern climates, and rye bread is commonly used in Germany and the Scandinavian countries Barley thrives in more arid sections, in the United States, it is used chiefly as pearl barley in soups and barley flour for infant feeding. Oats do not make good bread but are eaten as oat cakes (in Scotland and Sweden) and as porridge In amount produced, corn is the main grain product of the United States, but most of it is used for feeding animals, only 10–15 per cent of the corn crop goes for human consumption, and much of this is used for the manufacture of corn sirup (glucose) and corn starch, rather than being consumed directly as hominy grits or corn meal

In preparation for human food, all grains must be *milled,* and the extent of this milling process determines how much of the original nutrients in the whole grain are left for human consumption The husk and coarser bran coatings are removed for the sake of greater digestibility, the germ is usually removed to keep flour from spoiling when it must be stored for long periods In highly milled products, all the outer coats of the grain are removed and only the starchy inner portion (endosperm) remains. Much of the protein and mineral salts, and nearly all of the B-complex vitamins including the important B_1 or thiamine, are lost when the outer coats and germ are removed in highly milled grain products How large a place grains may safely occupy in the diet depends, at least in part, on whether they are used in the whole grain or in a highly milled condition For a diagram of distribution of nutrients in the wheat grain see Figure 79, page 231

All grain products (highly milled or otherwise) are characterized nutritionally by their high content of starch (nearly 70–80 per cent) and moderate content of protein (ranging from 7.5 to 14 per cent) Hence they serve as ***economical sources of energy*** and of some ***protein.*** The protein content will be somewhat higher and of better quality if only the coarsest bran has been discarded and some outer coats and the embryo are retained Likewise, the highly milled product will contribute little of minerals and vitamins, but the whole grain products (or those that have been "enriched") will be excellent sources of iron, thiamine, and niacin. In addition, the grain products are readily handled in large amounts by the digestive tract and make for favorable texture of the food residues

Nutrients that the grains *do not supply* in any considerable amounts

Different Food Groups and Their Place in the Diet

In the discussion of each of the essential nutrients in the preceding chapters, we have pointed out the best food sources of each nutrient, giving tables as to its distribution in typical foods. It seems worth while to gather this scattered information together by considering the groups of like foods and what each group may be counted on to supply or not to supply in nutrients, how they supplement each other, and the relative importance that may well be assigned to each group in a balanced diet.

Cereal Grains

Cereal grains are seeds of the grasses. From the beginnings of agriculture they have been the chief reliance of all peoples for their food supply. They are easily cultivated and stored, and can be brought by relatively simple processes into the form of palatable, wholesome, economical food. They are usually crushed into a fine meal or flour and made

into bread, which is often leavened by yeast. Bread has thus been for centuries literally "the staff of life" of many nations, especially of those of Europe and America

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Nutrients that the grains *do not supply* in any considerable amounts

are calcium, vitamins A and C, and riboflavin. Also, to be satisfactory for growth and reproduction, the proteins in grains need to be supplemented (in moderate extent) by some protein richer in the essential amino acids lysine and tryptophan. Milk or some other animal protein will meet this need. There has been a trend among nutritionists to improve the nutritional quality of bread as to calcium and protein by addition of milk solids (at 4–6 per cent level), or by incorporating in the dough some soybean or peanut flour, wheat germ, or dry yeast of high protein content. Of course the supplementation may be accomplished by foods taken separately, such as the fresh milk, meats, or eggs in the ordinary mixed diet, with citrus fruits or other fresh fruits for vitamin C.

In various surveys of American dietary habits, grain products were found to account for 11 to 18 per cent of the total cost of food, and for this outlay they contributed 30–40 per cent of the total energy value and 28–37 per cent of the protein of the diet. When some of them were whole grain or enriched, they also contributed more than their quota of iron and thiamine. Sherman makes the statement that "the nutritionally improved breads . . . may now safely be utilized to supply as much as 40 per cent of the calories of the normal diet"[1] This is much more bread than most of us would care to eat—on a 2,500 C. diet it would amount to 15 slices of white enriched bread. The per capita consumption of bread has decreased in this country in recent years, but the wide use of grains in such foods as breakfast cereals, macaroni, pies, cakes, puddings, etc means that this food group still occupies a prominent position in the diet.

Legumes and Nuts

The legumes are seeds, and nuts, although technically they are hard-shelled fruits, are similar to seeds in composition. Hence, this food group resembles the grains more than any other group, but is characterized by having almost twice as much protein as grains. The dried legumes (beans, peas, lentils, and cowpeas), because of their low moisture content, show figures as high as 62 per cent carbohydrate (starch) and 25 per cent protein—figures that may be misleading since in the state in which we eat them, fresh or cooked dried ones, their protein content ranges from only about 3.5 to 7.5 per cent. Although they are often classed as "meat substitutes" an average serving of one of the legumes thus furnishes probably only about one-third as much protein as an average serving of meat The quality of their proteins tends to be inferior to that of animal foods, except for those of the peanut and soybean, which are adequate for growth However, legume proteins do supplement in satisfactory manner the proteins of cereal grains, and this is particularly true of the proteins of peanuts, soybeans, and peas, when combined with wheat; the addition of small amounts of peanut or soybean flour will improve the nutritive quality of white (wheat) bread.

1 Sherman, H. C., and Pearson, C. S., MODERN BREAD, p 103, Macmillan Co., 1942.

The digestibility of legume proteins is improved by cooking. Dried legumes and soybeans require long, slow cooking, and the large amounts of hemicellulose in beans often leads to intestinal fermentation and flatulence.

The nuts also have a relatively high protein content (7–18 per cent), but, instead of being rich in starch as are legumes, they have high fat content (roughly 50–70 per cent). Soybeans and peanuts (which are legumes) also are exceptions, in that they have high protein and fat, being more like nuts in this respect than like legumes. The proteins of nuts are apt to be deficient in some amino acid but serve excellently to supplement other proteins; the difficulty is that nuts are seldom eaten in large enough quantities to contribute greatly to the total protein intake. In a survey by the U. S. Department of Agriculture, dried legumes and nuts accounted for only 1 per cent of the food money, and for this outlay they furnished 5 per cent of the protein, 11 per cent of the iron, and [illegible] per cent of the vitamin B_1 of the total diet.

In the discussion of food sources of mineral elements and B-complex vitamins, it may be recalled that legumes (especially dried) and nuts usually ranked high in the list of such sources. They are excellent sources of *phosphorus, iron,* and *thiamine* (B_1) and fair sources of calcium and riboflavin (B_2). Their weak points are that they are practically entirely *lacking in vitamins A and C*.

It may be said that this food group deserves a greater prominence in the diet than it is likely to receive. Although they are about the cheapest source of protein and are used more generously in low-cost diets, dried legumes have never been very popular with Americans. The increasing popularity of the peanut butter sandwich is a good sign. Although soybeans and peanuts are being more widely cultivated now, the general practice is to press out the valuable oils and feed the remaining

Potatoes and Sweet Potatoes

non-fat flour to animals. This flour, so rich in nutrients, could well be used for human food, mixed with wheat flour in bread, muffins, cookies, etc.

White potatoes and sweet potatoes are not related botanically but both are bland foods that can be eaten in quantity and furnish energy at low cost, since they are high in carbohydrate. The white potato has 19 per cent starch, while the carbohydrate content of the sweet potato (28 per cent) includes 5 to 8 per cent of sugar. Because they are approximately three-fourths water, their mineral and vitamin content does not look impressive but, when eaten in quantity, they may make considerable contribution to safeguard the diet in these respects. These two foods will furnish more than their quota of iron and thiamine but are low in calcium. *Because of their high potassium content,* white potatoes are of special value in building up the "alkaline reserve" of the body. The

valuable contribution of vitamin C which potatoes make to the diet was noted under the discussion of scurvy prevention. Retention of their mineral and vitamin content requires due care in cooking procedures. The protein of potatoes, although low in amount, has been shown to be of good nutritive value. White potatoes have almost no vitamin A value but sweet potatoes show a vitamin A value of 1,500 to 7,700 I.U. per 100 grams, varying with the depth of color. If sweet potatoes were served somewhat more commonly, they would bolster the ordinary vitamin A intake

It may be well to call attention to the fact that potatoes and sweet potatoes are not the only "starchy" vegetables. Such vegetables as lima beans, green peas, and sweet corn are also starchy, while beets and carrots contain sugar If starchy vegetables are consumed too freely, they contribute to production of overweight In certain European countries, potatoes have a larger place in the diet than in the United States. When they are economically able to do so, people tend to eat less of these low-cost staple foods and shift toward more diversified diets.

Green and Yellow Vegetables

Green and yellow vegetables are grouped together because they contain *carotenes*, which are the precursors of *vitamin A*, and constitute our vegetable sources of this vitamin. They may be subdivided into the leafy vegetables, other green vegetables, and yellow vegetables, because of differences in their contributions to the diet other than vitamin A value

LEAFY VEGETABLES Leaves are the most active parts of a plant, the chemical laboratories in which (with the aid of sunlight and chlorophyll) are built various substances necessary for life of the plant Hence they are characterized by being richer in mineral elements and vitamins than are other parts of the plant. They are especially rich in *calcium* and *iron*, in *provitamins A*, *ascorbic acid* (C), and *riboflavin* (B_2), with a good content of other B vitamins McCollum has emphasized that they supplement grain products, especially as to calcium and vitamin A value The calcium in a few leafy vegetables is mostly non-absorbable, because it is bound in insoluble combination with oxalic acid, but these vegetables nevertheless are valuable sources of iron and vitamins (A, C, and B_2). The ones with "bound" calcium are spinach, chard, sorrel, parsley, and beet greens, in other leafy vegetables the calcium is in forms available to the body Both in calcium and in vitamin A value, they rank next to milk as important sources. The ascorbic acid is so high in broccoli, Brussels sprouts, collards, kale, mustard greens, and turnip greens (94–136 mg per 100 gm) that, if cooked for a short time in small amounts of water, they will still be richer in vitamin C than the citrus fruits. Their iron content, fairly well utilized, is a valuable contribution to the diet Their energy and protein values are negligible. The chief

drawbacks to their consumption are their bulk and the fact that th are so fibrous as to be irritating to the intestine in some persons

The greener the leaf, the more actively it functions, and so the rich it is in vitamins and minerals. The blanched inner leaves of lettuce, ca bage, or celery are no richer in mineral salts and vitamins than are t stalks or roots of some other plants which are used as food.

OTHER GREEN VEGETABLES These are usually stalks, stems, or gre pods Young shoots (such as green asparagus tips) are high in vitam A value and similar in other composition to green leaves Broccoli a cauliflower (which consist of flowerets with some leaves) are or slightly less high in certain minerals and vitamins than leafy vegetabl Green snap beans and peppers represent pod vegetables, which are int mediate between the green leaves and the roots in minerals and vit mins. Most lettuce and cabbage ranks lower in vitamin A value than t deep green leaves Blanched celery and asparagus have little vitamin value

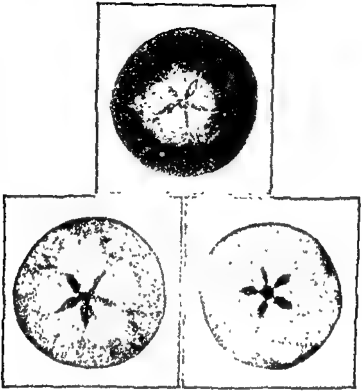
YELLOW VEGETABLES. This category includes fleshy roots (carro sweet potatoes, and rutabagas), fruit parts of plants (pumpkin, wint squash, cantaloupe, and other yellow fruits), and yellow corn The vi min A value varies with the depth of yellow color, but in deep-color varieties it is of almost the same magnitude as that of the green leav These vegetables contribute relatively small amounts of the other vi mins and of mineral elements, although in quantity they may be count on to supply some of these nutrients

Citrus Fruits and Tomatoes

These are grouped together as relatively rich sources of vitamin which are reasonably inexpensive and well enough liked to be consum in quantity They also hold their vitamin C content well on cooking canning. Grapefruit, lemons, and oranges have higher ascorbic acid co tent (40–50 mg per 100 gm) than tomatoes (23 mg). Other than th vitamin C content, citrus fruits contain about 10 per cent of readily a similable sugar along with some calcium and thiamine Tomatoes ha considerable vitamin A value (1,100 I U per 100 gm)

In planning an adequate diet, it should not be overlooked that the are other foods whose vitamin C content equals or exceeds that of citr fruits and tomatoes We have previously called attention (p 308) to su green vegetables as broccoli, kale, and turnip greens for high vitamin value, green peppers carry vitamin C in the same magnitude (129 m per 100 gm), while strawberries (60 mg per 100 gm) are also rich than oranges If one of these foods is used in the day's meals, it will n be necessary to include citrus fruit or tomatoes Also, if tomatoes a chosen as the vitamin C–rich food of the day, it will take about twi as large a quantity to furnish the daily quota as it would if orange jui were used The cheapest food sources of vitamin C are said to be cann

A



B C

Figure 101. Apples [illegible]

orange or grapefruit juice, all processed orange juice accepted by the Council on Foods of the American Medical Association must supply a minimum of 40 mg. per 100 cc (a little over 3 fluid ounces) of retained, naturally occurring ascorbic acid.

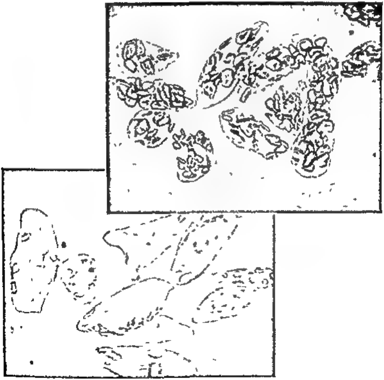
Other Fruits and Vegetables

All fruits and vegetables (including those listed in the special groups above) are of value in the diet for their *laxative* and *base-forming* properties, and as carriers of *mineral elements* and *vitamins* Together with milk, they serve to supplement the deficiencies of those foods on which we depend largely for meeting our energy and protein needs—foods such as highly milled cereals, sugar, fats, and meats. Thus, even though they furnish little energy and protein, fruits and vegetables are *essential* for the sake of other nutrients that they carry and that must be furnished in adequate amounts for health Increasing the quantity and

variety of fruits and vegetables in the diet will usually improve its quality

We are dependent almost entirely upon fruits and vegetables for vitamin C, and all of them carry some of this vitamin, especially if eaten raw Canned fruits carry lesser amounts of this vitamin, and in dried fruits it has been practically completely destroyed Dried fruits are rich in mineral elements, especially apricots, peaches, prunes and raisins for iron content Most fruits are poor in vitamin A value, exceptions are apricots, yellow peaches, prunes, avocados, and cantaloupe, which are good sources of vitamin A Since most fruits and vegetables consist of 75–95 per cent water (and some fiber), the B-complex vitamins and mineral elements are usually present in dilute conditions, so that a large bulk of them would have to be consumed if they are to add appreciably to the intake of these nutrients

Few persons could eat the 2 to 3 pounds of fruits and vegetables that Sherman hopefully suggests to be included in the diet daily, but



most of us could plan to get three servings of vegetables (including potato) and two servings of fruit daily Those who care less for vegetables can eat more fruit or green salads; those who do not tolerate these foods well in raw condition may eat them cooked, and if necessary puréed, those whose economic resources are limited can use the smaller number of fruits and vegetables that are less expensive staples (apples, bananas, canned tomatoes, dried fruits and legumes, etc.). If the demand for this class of foods is increased, they will be made available in larger amounts and at cheaper prices.

Milk

Milk is especially important in the diet for its outstanding contributions of (1) *high quality protein*, (2) *calcium*, and (3) *riboflavin* In addition, it provides some of practically all other essential nutrients in well-balanced amounts and in easily assimilated forms.

The chief proteins in milk are casein and lactalbumin, together they form a protein mixture which is so rich in those essential amino acids required for tissue building that it is more efficient in promoting growth than any other proteins, except those in eggs They also supplement the incomplete proteins found in the grains better than any other food proteins. *Lastly, milk is a fairly economical source of protein, only the cereals* and legumes furnish protein at less cost, and their proteins are not of as high quality as those of the animal foods.

In American dietaries, milk is usually the chief mainstay for calcium and riboflavin. No other common food (except its product, cheese) approaches it for richness in calcium, and it is extremely difficult to plan a dietary that provides the standard allowance of this element without use of a moderate amount of milk (or cheese and ice cream). A quart of milk will furnish enough calcium to meet the total daily allowance for a child up to 10 years of age, a pint will provide about 70 per cent of the daily allowance for an adult. Along with the calcium, milk provides the other element needed for building strong bones and teeth, phosphorus, and these two mineral elements are present in a ratio to each other that favors excellent utilization Milk's contribution of riboflavin (vitamin B_2) is almost as outstanding as that of calcium among the minerals. In a Department of Agriculture survey of American diets (1942), the food group of milk, cheese, and ice cream accounted for 17 per cent of the average food expenditure, while it furnished 65 per cent of the calcium and 43 per cent of the riboflavin Since these two nutrients are among those most likely to be supplied in less than optimum quantities, and since a goodly surplus of these nutrients has been shown to be conducive to better health, it is obvious that liberal use of milk in the diet is a wise procedure.

Milk is a good "buy" for other nutrients besides calcium and riboflavin. It is a dilute food—87 per cent water. Its 13 per cent of solids is

fairly evenly distributed between proteins, fat, and milk sugar (lactose) and these foodstuffs supply considerable energy (666 calories per quart The proteins, as stated, are of particularly high quality and do no putrefy in the intestine as readily as most other animal proteins do Th fat (and the vitamin A it carries) is in finely divided or emulsified condi tion, which favors its digestion and absorption The lactose does no ferment or cause digestive disturbances as readily as other sugars d The fact that milk is precipitated in "curds" in the stomach by the en zyme rennin and the hydrochloric acid of the gastric juice keeps from passing out of the stomach too quickly and favors its digestion

Since its function in nature is to serve as the sole food for youn animals, milk contains all of the vitamins and minerals needed for th purpose Both carotene and vitamin A are found in the fat globule varying somewhat with the feed of the cow, and variable amounts c vitamin D are also present The water-soluble vitamins are carried in th "whey." Milk contains only about one-fifth as much thiamine as ribo flavin, but all of the family of B vitamins are present, including B_{12} A though fresh milk contains moderate amounts of vitamin C, much of th may be lost in handling, storage, and pasteurization, so it is not to b depended on for this factor The content of iron and copper in milk rather low, but the iron is well assimilated

Milk production and consumption has increased in this country i recent years but is still below that recommended by nutritionists Nearl half of the milk produced is used in manufacture of dairy products (but ter, canned milks, cheese, and ice cream), after this is deducted, ther is left a little over one pint per person per day Children often get mor than this amount, which means that many adults must be taking les than a pint a day, including that used in cooking An estimate of mil consumption in cities made in February, 1950, found milk and its prod ucts (other than butter) were used in amounts equivalent to 4½ quart per person per week Nutritionists would like to see this raised to a quar daily for each child and at least a pint for each adult

Both for amount of food consumed and for man-hours of labor, dair cattle have been shown to return two to three times more food energ and protein in the form of food for humans than do beef cattle or sheep Egg and poultry-meat production is intermediate in efficiency betwee the production of beef (meat) and of milk Hence, a larger number o dairy cows and a smaller number of beef cattle would mean a more ec onomical use of the grains used for animal feeds

Milk Products (Other Than Butter)

Many people prefer to consume at least part of their milk allowanc in the form of milk products rather than as fluid milk They all share th nutritive properties of milk, in greater or less degree Lack of space pre vents little more than their enumeration here.

most of us could plan to get three servings of vegetables (including potato) and two servings of fruit daily. Those who care less for vegetables can eat more fruit or green salads, those who do not tolerate these foods well in raw condition may eat them cooked, and if necessary puréed, those whose economic resources are limited can use the smaller number of fruits and vegetables that are less expensive staples (apples, bananas, canned tomatoes, dried fruits and legumes, etc.). If the demand for this class of foods is increased, they will be made available in larger amounts and at cheaper prices

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CHEESES Cheeses vary considerably as to water content (hard and soft cheeses) and in fat content, depending on whether they are made from whole or skim milk They contain all of the casein and fat of the milk from which they were made, but usually some of the lactalbumin and calcium are lost in the whey that separates from the curd used for the cheese In "ripened" cheeses, the protein has been partially digested and rendered more soluble by bacterial action American (cheddar) cheese is a hard cheese (37 per cent water), so is a concentrated source of all milk solids, cottage cheese (as made from skim milk) is low in fat and high in protein, but has only about one-seventh of the calcium content of American (cheddar) cheese, cream cheese differs from other soft cheeses in having more fat and less protein Cheeses are excellent food and their consumption could well be increased

ICE CREAMS Ice cream is such a popular form in which to take part of one's milk quota that it needs little more than mention Ice creams vary widely in composition, depending on substances added, but average plain ice cream has about the same protein and calcium content as fresh whole milk, with considerably higher fat and carbohydrate content and hence higher caloric value

FERMENTED MILKS Fermented milks may be either from fat-free milk (buttermilk) or whole milk (koumiss, yogurt, acidophilus milk, etc) They are made by fermentation with various strains of bacilli that convert the lactose to lactic acid or alcohol McLester and Darby[4] state that "They are good foods, but have none of the mysterious health-giving virtues which are attributed to them by some present-day food faddists "

Eggs

Eggs are more nearly interchangeable with milk than is any other food, although there are some decided differences between them The main differences between the two foods are that (1) eggs have only about half as high calcium content as milk, (2) eggs are rich in iron, while milk is low in this element, and (3) eggs are a highly acid-forming food, while milk furnishes a slight excess of base-forming elements to the body.

The general composition of eggs is roughly three-fourths water, one-eighth protein, and one-eighth fat The protein is about equally divided between the white and the yolk, but all of the fat, as well as the mineral elements and vitamins (except riboflavin), are in the yolk The proteins of eggs are practically as efficient for promoting growth and supplementing deficient vegetable proteins as are those of milk, egg fat, like milk fat, is finely divided or emulsified, so that it is digested with special ease Eggs are a less economical way to buy protein than milk or

[4] McLester, J S, and Darby, W J. NUTRITION AND DIET IN HEALTH AND DISEASE, p 162 Saunders, 6th ed, 1952

Figure 103 Curds obtained by coagulating different kinds of milk with acid and the enzyme from gastric juice 1, human milk, 2, evaporated cow's milk plus water, 3, raw cow's milk, 4, cow's milk boiled only one minute The curds in (1) and (2) are about the consistency of cooked oatmeal, those in (3) and (4) are tougher and more solid, so that they can be cut with a knife (Courtesy of Rice and the Archives of Pediatrics)

CREAM Light cream has about six-sevenths of the protein content of fresh milk and five times its fat content, heavy cream carries about nine times as much fat as whole fresh milk Cream is a luxury substitute for milk, and in fact is not a real substitute, since the content of protein, calcium, and riboflavin is decreased as the fat content goes up

CANNED MILKS Canned milks meet the need for a concentrated, preserved milk which is economical to transport In all of these products much of the water is removed by evaporation in partial vacuum at fairly low temperatures, with little resultant loss of vitamins other than vitamin C They owe their keeping qualities to the following facts:

- Dried milk powders . . keep because of low water content (only 3.5 per cent)
- Condensed milks keep because of added sugar (about 50 per cent of final product)
- Evaporated milks keep because they are sterilized in the can—no sugar is added but about half of the water is removed

Evaporated milk is used in infant feeding for the sake of its softer, finer curd, in comparison with that formed by raw milk Condensed milk is a good substitute for cream in coffee and will keep indefinitely in an opened can, if refrigerated Dried milk powders are much used in commercial bakeries Dried skim milk is the cheapest form in which to purchase milk, it may be reconstituted or used dry in cookery processes Its use in breads, batters, cream sauces, and soups is an excellent way to reinforce the diet as to protein, calcium, and riboflavin

plentiful (United States, Canada, Australia, New Zealand, and Argentina) meat production and consumption are high, in populous countries (such as in Asia) where land is at a premium and must be used for "direct crops" in order to get enough food for humans, very little meat is available Only when cattle and sheep are raised on grazing lands and pigs and chickens more or less on refuse, does meat production represent the most economical use of national resources

One set of figures,[3] given below, show approximate *yearly consumption* of meats (beef, lamb, pork, etc.), poultry meats, and fish (including shellfish) *per person* in the United States.

Meats	155 pounds
Chicken and turkey	28 "
Fish	11 "
Total flesh foods	194 "

This amounts to a little over ½ pound per day for every person in the country As many persons eat less than this, some people must be very heavy meat eaters to keep the average at so high a figure Another study made in the Department of Agriculture[4] showed that about one-fourth of the family food budget went for meats at all income levels The most recent government survey,[5] made in 1955, shows consumption of meats still high (averaging 14½ pounds weekly per family) and expenditure for this food group now up to 36 cents of every dollar spent for food

Nutritionists have no quarrel with meats as excellent food but many of them believe that the American people would have a diet of higher nutritive quality if they spent less money on meats and more on some of the "protective foods" rich in minerals and vitamins On the other hand, meat contains good protein in concentrated form, it takes about 1½ pints of milk or 3 eggs to replace the protein furnished by the average serving of meat One medium-sized serving of meat daily is a great help in securing an adequate protein intake. Meat in the main meal of the day gives a sense of satiety because the meal leaves the stomach less quickly, as the old saying goes, "Meat sticks to the ribs" One should not lose sight of the fact that the same amount of meat may be purchased for less money, if the cheaper cuts are chosen and cooked in an appetizing manner

The flesh of all animals (mammals, birds, fish, or shellfish) is essentially the same, the difference in composition in flesh from different portions of the same animal is sometimes greater than the usual variation between the flesh of different animals Variations in composition are due chiefly to differences in *water* or *fat* content These are a good deal de-

[3] Consumption of Food in the United States, 1909–1948, U S Dept Agric, Misc. Pub No 691, 1949

[4] Commodity Summary No 1, based on 1948 Food Consumption Surveys, Bureau of Human Nutrition and Home Economics, U S Dept Agric, 1949

[5] "Food Consumption Survey," Reports No 1 and 6, U S Dept Agric, 1956 and 1957

cheese, but usually provide it at lower cost than meats, in addition eggs are rich in some mineral elements and vitamins that meat lacks.

Egg yolk (like milk) is prepared by nature to serve as food for young, growing animals, and hence contains practically all the essential minerals and vitamins, some in higher concentration than others. It is rich in phosphorus, sulfur, iron, and vitamin A plus carotene, it is a fair source of calcium and of the B vitamins, it is the richest food source of vitamin D (though no foods carry much of this vitamin). Eggs are completely lacking in ascorbic acid or vitamin C. In mineral elements and *vitamins, eggs supplement milk in respect to certain constituents* and in respect to others they supplement meats All three of these protein foods need to be supplemented for vitamin C by fruits and vegetables

Eggs are easily cooked in a variety of ways so that they form an acceptable *meat substitute* Their ease of digestion and high content of tissue-building nutrients make them a valuable food for *growing children* or *convalescents*. They are especially useful in *cookery*, where they serve *the purposes of thickening (as in custards) or stiffening and lightening* texture (as in batters and doughs). Our consumption of eggs in 1947 was about 6 per person per week, including those used in home cookery and in commercial bakery products. The Food and Nutrition Board has recommended at least 3–5 eggs per week in their pattern for an adequate diet. Too high a consumption of eggs is not to be recommended, especially for older persons, because of their high content of cholesterol, a fatlike sub*stance normally present in blood but which in excess may be a liability* for older persons Although the consumption of eggs may not be evenly enough distributed (they are fairly expensive), it would seem that our *average* consumption is up to nutritional standards.

Meats, Fish, and Poultry

These "flesh foods" are similar in composition and in their place in the diet Their outstanding contributions to the diet are (1) high quality *protein* in concentrated form, (2) *B vitamins*, especially riboflavin and niacin, and (3) *iron* The proteins of meat are somewhat similar to those of milk and eggs in their amino-acid make-up and, therefore, in the efficiency with which they supplement those of the cereal grains and some other vegetable proteins Only as to protein do the meats supplement grains, as both grains and meats are poor in calcium, and in vitamins A and C. Both contain fair amounts of phosphorus and iron and are good sources of the B vitamins, while both are acid-forming in the body.

Meats are well-liked foods and give a certain sense of satiety, so that they are usually consumed in larger amounts if the economic level permits and have come to be associated with prosperity and, psychologically, with "a higher standard of living" Nutritionally, their place in the diet can be entirely met by the use of milk, cheese, and eggs, as often happens in the diet of vegetarians In countries where grazing land is

vitamins Vegetable oils contribute vitamin E and, along with butter fat, provide the essential unsaturated fatty acids that are characteristic of low-melting-point fats Thus fats are interchangeable from the point of view of body fuel but not for vitamins and essential fatty acids

All fats are *one-sided foods* They are completely lacking in protein, mineral elements, and all the water-soluble vitamins Hence they must be supplemented in the diet by other foods that provide these nutrients essential for good nutrition In order to assure a well-balanced diet, it is generally stated that not more than 25–35 per cent of the fuel value of the diet should come from fats. As fats are such a concentrated fuel food, this will mean a relatively small bulk of fat daily Our present average consumption of fats is approximately at a level of 40 per cent of the calorie value of the diet Many nutritionists believe this high a consumption of fats is responsible for prevalence of overweight and some consider it may contribute to the tendency to hardening of the arteries (arteriosclerosis) and high blood pressure Hence, they feel that reduction of fats to nearer the level of 25 per cent of the fuel intake would be advisable In Oriental diets fats often furnish no more than 10 per cent of the calories, but western peoples want more fat in the diet both for flavor and satiety value

Fats vary widely in cost, and economic considerations may cause people to alter the amount or kinds of fats consumed Relatively cheap fats, such as lard and salt pork, may furnish inexpensive fuel in low-cost diets Pure imported olive oil is now so expensive as to induce people to make use of refined cottonseed, peanut, or corn oil instead for salad dressings The popular demand for margarine as a less expensive substitute for butter has given rise to its fortification with vitamin A up to the level of average butter and to the withdrawal of federal taxes on it and in many states to repeal of the laws that forbade its yellow coloration Since the preference for certain fats rests on habit and minor flavor factors, it is well that various fats should be brought into more general use as economic conditions make it seem desirable

Sugar and Concentrated Sweets

These foods furnish *energy* in relatively inexpensive, readily digested, and quickly available form, they also are useful for *flavor* and have some satiety value They are practically completely *devoid of protein, minerals, and vitamins*

We use sugar chiefly as refined cane sugar or beet sugar (sucrose). Corn sirup, a concentrated solution of glucose, has considerable commercial use in making candies, jams, and bakery products. Fresh fruits contain sugars (sucrose, glucose, and fructose) in dilute solution, dried fruits contain them in greater concentration Including sugar consumed in candies, sirups, jams, and jellies, as well as for table use and in cooking, sugar consumption in the United States amounts to over 100 pounds

pendent on the species, e.g., fish is usually higher in moisture content than beef or lamb, salmon is relatively high in fat, compared with cod or flounder, and pork is richer in fat than most other meats. The fat content also varies in different cuts of meat and according to previous feeding Fat that is in layers outside of the lean portion is usually discarded and should not be counted in the caloric value of the meat as eaten; fat may also be lost in the "drippings" during cooking In pork, considerable fat is between the muscle fibers, which adds greatly to the fuel value but makes this meat more difficult to digest Lean muscle meats may be described as consisting of approximately one-fifth protein, three-fourths water, and one-hundredth ash (with varying small amounts of fat). They also contain small amounts of connective tissue, which holds the muscle fibers together, and of extractives, which give the flavor to meat soups

There are some variations in mineral elements and vitamins Pork is many times higher in thiamine (vitamin B_1) than other muscle meats. Fatty fish (e g, canned salmon) have a good content of vitamin D The glandular organs, such as liver and kidneys, are especially rich in vitamin A, the B vitamins, and iron. The iron in these organs is 100 per cent available for building hemoglobin, but there are differences of opinion as to the extent of availability of iron in muscle meats All lean meats are good sources of phosphorus. Salt water fish and shellfish are good sources of iodine, which is a scarce element in foods

The effect of cooking on the vitamin content of meats also deserves mention Meats contain little vitamin C (ascorbic acid) even in the raw state and practically none after cooking The loss of B vitamins in cooking varies with the vitamin and with the method of cooking Thiamine (the most heat-labile B vitamin) may be lost to the extent of 50–75 per cent in stewing or braising, 30–50 per cent in roasting, and 10–15 per cent in frying

Fats

Fats serve three main purposes in the diet—(1) furnish *body fuel* in *concentrated* form, (2) improve *flavor* and *satiety value* of food, and (3) weight for

of animal

semisolids

like butter) and *those that* are in *emulsified form* (*as in milk, butter,* and egg yolk) are more easily (but usually not much more completely) digested than those of higher melting points. Foods in which fat is intimately mixed with protein or starch (fatty meats, rich gravies, sauces, pastries, and cakes, and foods that have absorbed much fat in frying) are relatively hard to digest and may slow digestion of other foods enough to cause digestive distress Although vegetable oils are just as good *fuel*, they do not contribute any of the fat-soluble vitamins A and D, butter (or fortified margarine) and egg yolk are good sources of these

ones? In respect to what nutrients does it supplement the grains? the legumes? lean muscle meats? Name some of the milk products that may, at least in part, be substituted for fresh whole milk in the diet. What is the least expensive product in which one can buy milk solids?

5. For what reasons are meats, fish, poultry meat, and eggs especially valuable in the diet? In respect to the nutritive essentials that they provide, how do lean meats resemble and how do they differ from milk? How do eggs differ from meats and from milk in these respects? From the point of view of cost to the national resources, which of these types of food is most costly and which is most economical to produce—grains, milk, eggs, beef? Is this reflected in their market cost?

6. Of what value are fats and sugar in the diet? What are their shortcomings as foods? To how great an extent may they safely be included in the diet? What dangers may be associated with too high consumption of fats, of concentrated sweets?

7. After looking at the figures on the relative consumption of the various groups of foods in this chapter and their relative contributions to the diet, which groups would you say might well be consumed in lesser and which in greater amounts, for the sake of nutritional welfare?

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per person yearly, or about a half pound each day for every person in the country. Our annual candy bill is over a billion dollars and has increased over 1000 per cent in the last 60 years.

In studies of American family dietaries (1942), sugar and other sweets accounted for only 3 per cent of the total food cost but furnished 8 per cent of the total energy, which bears out the fact that sugar is one of the cheapest forms in which to buy energy, its other contributions of essential nutrients were negligible. If such a one-sided food is allowed too prominent a place in the diet, there will be a shortage of the essential proteins, mineral elements, and vitamins. It should be used chiefly as a flavoring material, *in more dilute forms (fresh fruits), or at the end of* meals (desserts). The satiety value of sugar is due to the fact that it acts to depress the appetite, not as with fats in slowing emptying time of the stomach. When taken in concentrated form or in excessive amounts, especially on an empty stomach, it may irritate the lining of the stomach or cause distress by fermenting in the intestine Also much sugar in the diet has been shown to be a contributing factor in causing tooth decay, overweight, and diabetes. For all of these reasons, it is recommended that not more than 5 to 10 per cent of the body fuel supply should come from sugar and other concentrated sweets

QUESTIONS AND PROBLEMS

1. What are the chief contributions of grains and their products (bread, breakfast cereals, etc) to the diet? In what nutritive factors are they rich and in which ones are they lacking? In what ways nutritionally do highly milled grains differ from whole grains, and why? Is enriched white bread nutritionally equivalent to bread made from whole grain? What suggestions have been made as to how the calcium content and quality of protein in wheat bread could be improved?

2. Are legumes and nuts good sources of protein? Inexpensive sources? Do any or all of them furnish protein mixtures that are complete as to essential amino acid content? Which ones are especially good for supplementing the proteins of wheat, and why? Are legumes and nuts "alternates" or complete "substitutes" for meats in the diet? Explain why. What mineral elements and vitamins are found in good or high quantities in legumes and nuts?

3. For what vitamin are we almost entirely dependent upon fruits and vegetables? For what other reasons are these classes of foods needed in the diet? How do they act as body alkalizers? What are the special nutritive contributions made by each of the following sub-groups: potatoes and sweet potatoes? green and yellow vegetables? leafy vegetables? citrus fruit and tomatoes?

4. In respect to what nutrients does milk make an outstanding contribution to the diet? What other nutrients does it furnish in lesser amounts? Is it low or lacking in any essential nutrients, and if so which

ones? In respect to what nutrients does it supplement the grains? the legumes? lean muscle meats? Name some of the milk products that may, at least in part, be substituted for fresh whole milk in the diet What is the least expensive product in which one can buy milk solids?

5 For what reasons are meats, fish, poultry meat, and eggs especially valuable in the diet? In respect to the nutritive essentials that they provide, how do lean meats resemble and how do they differ from milk? How do eggs differ from meats and from milk in these respects? From the point of view of cost to the national resources, which of these types of food is most costly and which is most economical to produce—grains, milk, eggs, beef? Is this reflected in their market cost?

6 Of what value are fats and sugar in the diet? What are their shortcomings as foods? To how great an extent may they safely be included in the diet? What dangers may be associated with too high consumption of fats, of concentrated sweets?

7. After looking at the figures on the relative consumption of the various groups of foods in this chapter and their relative contributions to the diet, which groups would you say might well be consumed in lesser and which in greater amounts, for the sake of nutritional welfare?

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per person yearly, or about a half pound each day for every person in the country. Our annual candy bill is over a billion dollars and has increased over 1000 per cent in the last 60 years.

In studies of American family dietaries (1912), sugar and other sweets accounted for only 3 per cent of the total food cost but furnished 8 per cent of the total energy, which bears out the fact that sugar is one of the cheapest forms in which to buy energy, its other contributions of essential nutrients were negligible. If such a one-sided food is allowed too prominent a place in the diet, there will be a shortage of the essential proteins, mineral elements, and vitamins. It should be used chiefly as a flavoring material, in more dilute forms (fresh fruits), or at the end of meals (desserts) The satiety value of sugar is due to the fact that it acts to depress the appetite, not as with fats in slowing emptying time of the stomach When taken in concentrated form or in excessive amounts, especially on an empty stomach, it may irritate the lining of the stomach or cause distress by fermenting in the intestine. Also much sugar in the diet has been shown to be a contributing factor in causing tooth decay, overweight, and diabetes For all of these reasons, it is recommended that not more than 5 to 10 per cent of the body fuel supply should come from sugar and other concentrated sweets.

QUESTIONS AND PROBLEMS

1. What are the chief contributions of grains and their products (bread, breakfast cereals, etc.) to the diet? In what nutritive factors are they rich and in which ones are they lacking? In what ways nutritionally do highly milled grains differ from whole grains, and why? Is enriched white bread nutritionally equivalent to bread made from whole grain? What suggestions have been made as to how the calcium content and quality of protein in wheat bread could be improved?

2. Are legumes and nuts good sources of protein? Inexpensive sources? Do any or all of them furnish protein mixtures that are complete as to essential amino acid content? Which ones are especially good for supplementing the proteins of wheat, and why? Are legumes and nuts "alternates" or complete "substitutes" for meats in the diet? Explain why. What mineral elements and vitamins are found in good or high quantities in legumes and nuts?

3. For what vitamin are we almost entirely dependent upon fruits and vegetables? For what other reasons are these classes of foods needed in the diet? How do they act as body alkalizers? What are the special nutritive contributions made by each of the following sub-groups: potatoes and sweet potatoes? green and yellow vegetables? leafy vegetables? citrus fruit and tomatoes?

4. In respect to what nutrients does milk make an outstanding contribution to the diet? What other nutrients does it furnish in lesser amounts? Is it low or lacking in any essential nutrients, and if so which

ones? In respect to what nutrients does it supplement the grains? the legumes? lean muscle meats? Name some of the milk products that may, at least in part, be substituted for fresh whole milk in the diet What is the least expensive product in which one can buy milk solids?

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Adequate Diets for Normal Adults

THE PRECEDING chapters have dealt in some detail with the various nutrients that must be furnished by an adequate diet, the amounts of each nutrient actually required and the recommended allowances,[1] as well as with the different food groups and the nutrients that each of them can be relied on to contribute to the diet. It remains to apply this information to the planning of diets that will be at least adequate, and *preferably more than adequate, in all essential nutrients.* Of course the ordinary individual is not going to sit down and calculate his diet to see whether it comes up to the standards set by nutritionists What he wants and needs is some general rule or set of rules, which will assure adequacy if followed in planning the diet In this chapter, we will discuss some of the plans suggested for this purpose, their application in planning diets for normal adults, and adaptation of such diets to fit individual needs.

1 Tables of recommended allowances of all nutrients for different classes of persons will be found in the Appendix (page 566) and should be referred to in studying this chapter.

Plans for Supplying Dietary Needs

A number of general plans have been suggested in the attempt to meet this need of "average" persons at different cost levels Although the earlier suggested plans all gave some guidance that would lead to improving the diet nutritionally, none of them *assures* an adequate diet under all conditions In our opinion, only the suggestion of the Food and Nutrition Board that the diet be planned around the "core" of a certain basic group of foods, called the "basal diet," or "foundation diet," will assure adequacy under modern conditions of food costs and for widely differing individuals' needs The four plans most frequently suggested are

(1) [illegible]
(2) [illegible]
(3) [illegible]
(4) [illegible]

Put in this way, it should be apparent why the first three plans will not guarantee an adequate diet under all circumstances The intake of calories will vary widely according to the amount of physical work done, and their allocation between different types of food will vary with the amount of money available for food (e g, a higher proportion of calories must come from grains and other starchy foods in low cost diets) The main value of the plan for allotment of calories is the insistence that, even in high calorie and low cost diets, sugar and sweets should furnish not more than 8–12 per cent and fats not much more than 18–20 per cent of the total calories of the diet These food groups furnish fuel alone, and other food groups must be well represented in the diet if it is to be adequate as to protein, mineral elements, and vitamins

The allocation of money to different types of food will vary at dif-

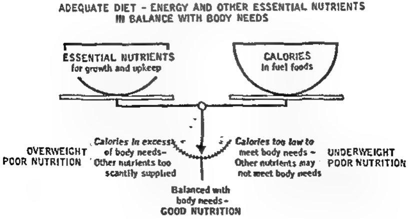

Figure 104

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ADEQUATE DIET - ENERGY AND OTHER ESSENTIAL NUTRIENTS IN BALANCE WITH BODY NEEDS

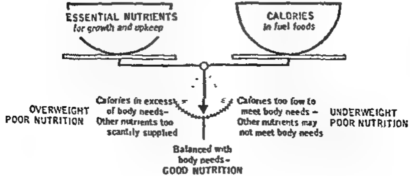


Figure 104.

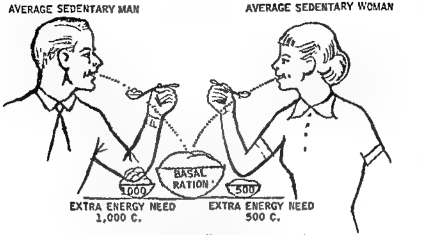
Table 17. Amount of Nutritive Essentials Supplied by Basal Ration and Standard Allowances for Average Sedentary Man and Woman

Nutritive Essential	*Basal Ration*	*Sedentary Man 70 kg. wt., 25 yrs*	*Sedentary Woman 58 kg. wt., 25 yrs*
Energy, calories	1400–1500 C.	2450–2550 C	1800–2000 C.
Protein, grams	70–72	70	[illegible]
Calcium, grams	0.8–0.9	0.8	0.8
Iron, milligrams	12	10	12
Vitamin A, I U	6500–7500	5000	5000
Thiamine, milligrams	0.8–1.0	1.6	1.2
Riboflavin, milligrams	1.6–1.8	1.8	1.5
Niacin equiv., milligrams	21	21	17
Ascorbic acid, milligrams	75–100	75	70

ferent income levels and as relative costs of certain types of food vary with the times or in different localities Foods that provide animal protein are usually relatively expensive (meats, eggs, dairy products), and meats are often unduly high. Yet even in low cost diets, these groups must be adequately represented if the *quality* of the protein intake is to be protected, even with using less meat and lower cost cuts of meat, more money may have to be spent on this type of foods if the diet is satisfying to the average American and adequate in high quality protein An irreducible minimum must go for dairy products in order to make the diet adequate as to calcium, and another minimum must be allotted for the fruits and vegetables that provide minerals and vitamins. Yet adjustments may be made to fit special circumstances, and no hard and fast rules of distributing expenditures can be followed safely.

The scheme of allocating a certain number of servings in each of the "7 basic food groups" is more adjustable and safer from a nutritional standpoint, because the fruits and vegetables are subdivided into special groups such as (1) citrus fruits and tomatoes, and (2) green and yellow vegetables, groups that should be represented in the diet to provide for ... but, with ... are put ... ne group except for the two special classes mentioned above, and sweets and fats are also grouped together. The main weakness is that, if the choice of foods within certain groups is not a wise one, or if size of servings (not specified) is small, the diet may still fall short in respect to some nutritive essentials

The plan which specifies definite amounts of certain types of foods in a *basal ration* or *foundation diet* seems to be the most "foolproof" and yet at the same time the most elastic The basal ration is depended on to provide practically the full allowances of all nutritive essentials except calories; the rest of the diet can be built around this group of foods with considerable freedom of choice Those who do not need many



Basal Ration Supplies All Other Nutrients in Amounts That Meet the Standard Allowances

Figure 105

extra calories will still get enough protein, minerals, and vitamins, while the other foods taken by those with high caloric needs may or may not add much of the other nutritive essentials The *foundation diet* suggested is as follows.

Milk—1 pint daily, for adults (1½ pints to 1 quart for children and adolescents)

dishes made with eggs or left-over meats)
Vegetables
1 potato, medium-sized
1 avg serving (100 gm) leafy, green, or yellow vegetable
1 avg serving (100 gm) other vegetable
Fruits
1 avg serving citrus fruit, tomato, or
other rich source of vitamin C
1 avg serving (100 gm) other fruit (fresh, canned, or dried)
Butter or fortified margarine, at least 2 tbsp or 1 oz
Bread and/or cereal—4 slices whole grain or enriched bread, or
3 slices whole grain or enriched bread
and 1 serving whole grain cereal

Table 17 shows the amount of the various nutritive essentials which the basal ration may be expected to furnish, compared with the standard allowances of these nutrients for the average sedentary man and woman It should be understood that the basal ration can be calculated only *approximately*, as the choice of foods in the same group will vary from day to day, while the serving of "other protein food" may vary widely in its composition.[2]

[2] Some of the figures for estimating the nutritive value of the basal ration are from the Food Composition Table for Short Method of Dietary Analysis, which gives *averages* for foods in the same group This table, as revised by Leichsenring and Wilson, may be found in J Am Dietet Assoc., 27, 386, 1951

Table 17. Amount of Nutritive Essentials Supplied by Basal Ration and Standard Allowances for Average Sedentary Man and Woman

Nutritive Essential	*Basal Ration*	*Sedentary Man 70 kg. wt., 25 yrs.*	*Sedentary Woman 58 kg. wt., 25 yrs.*
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Protein, grams .	70–72	70	58
Calcium, grams	0.8–0.9	0.8	0.8
Iron, milligrams	12	10	12
Vitamin A, I.U.	6500–7500	5000	5000
Thiamine, milligrams . .	0.8–1.0	1.6	1.2
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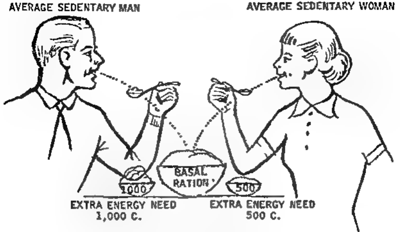
ferent income levels and as relative costs of certain types of food vary with the times or in different localities. Foods that provide animal protein are usually relatively expensive (meats, eggs, dairy products), and meats are often unduly high. Yet even in low cost diets, these groups must be adequately represented if the *quality* of the protein intake is to be protected, even with using less meat and lower cost cuts of meat, more money may have to be spent on this type of foods if the diet is satisfying to the average American and adequate in high quality protein. An irreducible minimum must go for dairy products in order to make the diet adequate as to calcium, and another minimum must be allotted for the fruits and vegetables that provide minerals and vitamins. Yet adjustments may be made to fit special circumstances, and no hard and fast rules of distributing expenditures can be followed safely.

The scheme of allocating a certain number of servings in each of the "7 basic food groups" is more adjustable and safer from a nutritional standpoint, because the fruits and vegetables are subdivided into special groups such as (1) citrus fruits and tomatoes, and (2) green and yellow vegetables, groups that should be represented in the diet to provide for vitamins C and A. A minimum amount of milk is also specified but, with exception of milk, all the protein foods (animal and vegetable) are put in one group, all fruits and vegetables (including potatoes) in one group except for the two special classes mentioned above, and sweets and fats are also grouped together. The main weakness is that, if the choice of foods within certain groups is not a wise one, or if size of servings (not specified) is small, the diet may still fall short in respect to some nutritive essentials.

The plan which specifies definite amounts of certain types of foods in a *basal ration or foundation diet* seems to be the most "foolproof" and yet at the same time the most elastic. The basal ration is depended on to provide practically the full allowances of all nutritive essentials except calories; the rest of the diet can be built around this group of foods with considerable freedom of choice. Those who do not need many



Basal Ration Supplies All Other Nutrients in Amounts That Meet the Standard Allowances

Figure 105

extra calories will still get enough protein, minerals, and vitamins, while the other foods taken by those with high caloric needs may or may not add much of the other nutritive essentials. The *foundation diet* suggested is as follows:

Milk—1 pint daily, for adults (1½ pints to 1 quart for children and adolescents)
Meats—1 serving (3½ oz. or 100 gm., cooked, edible portion)
1 egg (at least 3–4 per week)
1 serving other protein food (50 gm.)
  (may be extra milk, egg, cheese, legumes, nuts, or
  dishes made with eggs or left-over meats)
Vegetables
  1 potato, medium-sized
  1 avg. serving (100 gm.) leafy, green, or yellow vegetable
  1 avg. serving (100 gm.) other vegetable
Fruits
  1 avg. serving citrus fruit, tomato, or
    other rich source of vitamin C
  1 avg. serving (100 gm.) other fruit (fresh, canned, or dried)
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From Table 17 it will be apparent that supplementary foods will need to be taken that would supply about 1000 additional calories for the man and 450 calories more for the woman With regard to the other essential nutrients, the foods listed in the foundation diet will provide practically all (somewhat low in thiamine) the standard allowances set by the Food and Nutrition Board (1958). Since the standard allowances usually provide a "factor of safety" by being about 50 per cent higher than the actual *requirement*, a sedentary adult would not suffer a deficiency of any essential nutrient (except calories) on the basal diet. Persons of greater weight and those who do much muscular work will require considerable amounts of extra food and some high calorie foods to supplement the basal ration (up to 3500–4500 C. for a very muscularly active man) As such a person will usually need more protein and certainly needs a higher allowance of thiamine, at least part of the foods taken to supply extra energy should be of a nature that will boost the intake of protein, mineral elements, and vitamins This will be true in lesser degree for the person of average weight and sedentary habits, since health will be protected by a *surplus* of all the essential nutrients except calories.

Foods that may be used to add to the fuel value of the diet include sugar and cream in beverages and on foods, salad dressings, starchy foods, and rich and sweet desserts But too large a proportion of the extra calories should not be furnished by sugar, highly milled grains, and fats—foods that are poor or lacking in protein, mineral elements, and vitamins. The basal diet may be reinforced with advantage in its content of protein, calcium, and B vitamins, this will be accomplished if more milk and eggs (or dishes in which they are incorporated) and more servings of fruits and/or vegetables are taken than is specified as the minimum in the dietary pattern Whole grain bread and cereals, legumes, nuts, and cheese also furnish extra calcium and B vitamins along with extra calories. For instance, let us assume that the sedentary woman makes up her calorie requirement by addition of the following foods to the basal diet—

6 oz milk (med. glass), serving oatmeal, 1½ tbsp fat, 2 tbsp sugar, and a piece of frosted cake

This additional food not only will bring her caloric intake up to 2100–2200 C. but at the same time will bring the intake of other nutrients up to the following levels

Protein	85 gm	Vitamin A	7000 I U
Calcium	1 1 gm	Thiamine	1 2 mg
Iron	14 0 mg	Riboflavin	2 0 mg

The milk and whole grain cereal not only are responsible for reinforcing the diet in calories but give a margin of safety as to other nutritive es-

sentials She could do without the piece of cake, however, since this brings the calorie intake above what she probably needs and contributes little as to other nutrients

Variety: How Far May Substitutions Safely Go

Fortunately, the daily quota of nutritive essentials can be met by use of a wide variety of foods This not only avoids monotony but permits adaptation of the diet to suit individual tastes, to meet different economic conditions, and to use foods available in certain localities In some respects there is great freedom of choice, while in the case of certain food groups substitutions must be made with some nutritional "know-how" if the diet is to remain adequate as to all essentials Let us consider the diet in three sections, according to the relative freedom of choice that is permissible

FOODS OVER AND ABOVE THE BASAL DIET One may get the extra calories needed from almost any type of food As McCollum has said, "Eat what you want after you have eaten what you should" Almost the only precautions are to watch body weight, so that the calorie consumption will not be greater or less than individual needs, and to avoid taking too great a proportion of the calories in the form of fats and sugar If the calorie needs are high (larger and more active persons), some foods of high fuel value (such as fatty foods) will be needed to furnish the required energy without too great bulk However, such persons usually eat more heartily of various kinds of food, some of which contribute protein, minerals, and vitamins, along with energy In low-cost, high-calorie diets, where a large proportion of the energy is provided by grain products, at least half of them should be whole grain or enriched products

BASAL DIET SUBSTITUTIONS WITHIN THE SAME FOOD GROUP Substitutions within the same food group may be made rather freely, since foods in the same group contribute about the same essential nutrients With regard to the specific food groups in the basal diet, the following suggestions are offered

[illegible]

moderately large servings of ice cream are equivalent in calcium value to about ½ pint of milk)

Meat—Use red meats, fish, poultry, or shellfish interchangeably Cheaper cuts of meats have about the same nutritive value as more expensive ones Organ meats, such as liver should be used occasionally Canned or dried meat or fish is usually economical

Vegetables *Green and yellow vegetables*—These vegetables can be freely substituted within the group so as to use those that are better liked or cheaper in the market, can also use yellow fruits, such as apricots, in place of a yellow vegetable But the dark green, leafy ones are so much richer in vitamin A value, iron, B-vitamins, vitamin C, and usually calcium, that they should be used occasionally

Potatoes—It is not essential that potatoes be included in the diet daily, but the Food and Nutrition Board evidently considers that they should be dif-

may be freely substituted for each other, e g , beets instead of onions, summer squash in place of eggplant, cooked celery in place of turnip, etc Sweet potatoes of course belong with the yellow vegetables, and tomatoes with the citrus fruits for their content of vitamin C, i e , they may take the place of the recommended serving of that class of food on days when they are served

Fruits *Citrus fruits or tomatoes*—Any other rich source of vitamin C may be substituted for this spot in the diet, e g , cantaloupe, fresh strawberries, cooked broccoli or leafy vegetable, raw cabbage, etc. Orange or grapefruit may be used as fruit or juice, canned, or frozen concentrate, tomatoes may be fresh, as juice, or as canned tomatoes

Other fruits—Fresh, canned, frozen, or dried fruits may be used interchangeably but, if finances permit, use of fresh fruits is to be preferred. Dried

Bread an

highly milled grain is not a substitute for a whole grain product This is why the basal diet specifies a certain amount of whole grain or enriched bread

Fats—A certain amount of fat is needed in the diet for satiety value and essential fatty acids In order that this fat also contribute preformed vitamin A, either butter or fortified margarine is specified Extra fats taken may be vegetable oils or products made from them (cooking fats) as desired

BASAL DIET. SUBSTITUTIONS BETWEEN DIFFERENT FOOD GROUPS If substitutions between different food groups are necessary for economic reasons or because a person cannot take some types of food, considerable care must be exercised to see that the basal diet still is adequate in respect to all nutrients, as the foods in different groups are *not identical* in their contributions to the diet. For instance, approximately the same amount of protein will be furnished by either 3 oz. of lean meat, or 2½ cups of milk, or 1½ cups of cooked beans, the meat and milk contribute *better quality* protein, the milk would be high in calcium and the meat poor in it, while the meat and beans both carry much more iron than the milk. So these foods are not interchangeable except for the fact that they provide the same *amount* of protein. Hence, if we are going to use less meat or less milk than specified in the basal diet as desirable, several other foods will usually be required to furnish the nutritive essentials that the milk or meat was relied on to provide. It is wiser to follow the general dietary pattern laid down in the basal diet but, since adjustments must sometimes be made for various reasons, suggestions as to what foods or combinations of foods most nearly replace the nutritive contributions of certain food groups are given below.

Milk—Milk is the most difficult to replace adequately in the diet (except by milk

servings of other good sources of calcium to come up to the calcium contribution of much smaller amounts of milk, one may cut down somewhat on the amount of milk but it is unwise to omit it entirely

Eggs—An egg a day in the diet is not essential, 3–4 per person per week is considered advisable, including those used in cookery Either milk or meat, or a combination of the two, offers a good replacement for eggs

Meats—Many people use less meat than the amount specified in the basal diet More

(in milk, cream, butter, or fortified margarine) or from yellow fruits, but care must be taken to provide the other nutritive essentials from foods that are good sources of iron, calcium and B vitamins (milk, legumes, nuts, or dried fruits)

Citrus Fr

source is included in the diet daily For those whose intake of citrus fruits and other raw foods must be limited, supplementary vitamin C in tablet form is usually recommended

Fats—If one cuts down sharply on fats (as in a reducing diet), green and yellow vegetables should be consumed liberally to make up the quota of vitamin A, or vitamin A may be taken in capsules

Cereal Gr

Adapting the Diet to the Individual

Ways of adapting the diet for persons who cannot (or will not) eat certain types of food have been suggested in the foregoing section We will only briefly summarize a few other aspects here

The *division* of the basal diet *into meals* is left to the discretion of the individual, although it is assumed that most persons eat three meals a day Omission of breakfast is frowned on by nutritionists, as food is needed to supply energy and prevent fatigue during the morning hours; also, if breakfast is omitted or is too light a meal, it is difficult to make sure that the other two meals will include enough foods to furnish the daily quota of all nutrients However, the day's ration need not be divided into three equal parts Especially during the growth period (up to 20 years), it is important to have *some animal protein food in each* of the three meals, in order to provide all essential amino acids for tissue

Figure 106 Two types of "problem eaters" at the snack bar. He, although inclined to overweight, has a hearty dish on his plate, topped off with pie, cheese, and a chocolate malt, she, desiring to keep slender, has only a "Coke."

building, for breakfast, this could be taken care of by milk, to drink or on cereal, or an egg with toast. Too light, or one-sided, a lunch also means that not all of the foods in the basal diet may be consumed. Some persons do better on four or five smaller meals

Those who eat in restaurants or must take lunch away from home may have a little more difficulty in following a food pattern consistently. If the lunch is carried from home, the homemaker should plan it to supplement the home meals, so as to get in all the essential food groups in recommended amounts. If lunch is taken at a restaurant or cafeteria, the individual should make choices according to the foods likely to supplement those he gets usually in breakfast and dinner: if he takes coffee at breakfast, he should have a glass of milk for lunch in order to get his quota (1 pint) for the day, if he has meat for dinner, an egg dish or a salad made with some protein-rich food will help make up his protein quota for the day Those who eat three meals a day in restaurants usually have considerable choice of foods served, and should plan their own meals by such selections as will include the required number of servings of all food groups in the day's basal ration; they can then eat other foods as appetite and discretion dictate. If there is no meat one fancies, he can take fish, poultry, or a salad of shellfish, vegetables are usually the biggest problem, but salads or fresh fruit (instead of rich desserts) will often fill in for the lack of variety and tastiness, or small servings, of the vegetables provided. Milk, eggs, and whole grain or enriched bread or cereal are good foods to fill out the meal when there is little offered on the menu that appeals With a little knowledge of which foods are more or less equivalents in the daily pattern for an adequate diet, the restaurant eater can make selections that assure at least an adequate, if not an optimum, diet.

Perhaps two types of "problem eaters" should be mentioned. The first is the one with hearty appetite and good digestion, who likes to eat heavily of meat and potatoes, pies, ice cream, and cake. If possible, this type of eater should be persuaded, before filling up on the hearty foods which he specially likes, to take at least some of the milk, fruits, and vegetables needed for good nutrition, perhaps offered in dishes that would appeal. The other is the "finicky" eater, with poor appetite and usually various sorts of digestive difficulties, such a person often cannot take certain raw fruits or the coarser kinds of vegetables. Fruits may be cooked and skins and seeds strained out, some vegetables may need to be puréed, and those that are gas-forming or have very coarse fiber may have to be avoided, extra milk and eggs can be prepared in soft, bland, nourishing puddings. If the foods are selected properly and prepared to suit the more sensitive digestive tract, an adequate and balanced diet can be given, usually the need of such persons for calories and protein is also somewhat lower because of smaller size and lesser activity.

Individual Differences in Requirements and Proper Use of Recommended Allowances

Obviously there will be wide differences in calorie requirements, varying with sex, age, size, and especially with the amount of physical activity, the protein requirement will also vary with body weight and amount needed for building new tissues (growth or repair). The recommended calorie and protein allowances are given only for average or "reference" adults and are meant to be adapted to individual needs. The mineral and vitamin allowances, however, are given as the same for all adults (with slight differences between men and women, and a slight scaling of some of the B vitamins to size or calorie consumption). Yet we know that there is considerable difference between individuals in the efficiency with which they utilize these nutrients, so that some will get along all right on smaller amounts while others will require larger amounts supplied in the diet in order to meet body needs. A recent book[3] has emphasized the extent and frequency of such individual variations and the importance of taking them into consideration in planning the diet. The American standard allowances, based on the *average* requirement plus at least a 30–50 per cent surplus, are placed at a high level with the idea that this will cover the needs of even those who have high requirements.

Since we know that the majority of the population will have their nutritive *requirements* met by lesser amounts, it is certainly a mistake to assume that anyone whose intake falls below the standard allowance in one or more nutrients is necessarily getting an inadequate diet. Adults have been maintained satisfactorily over long periods on as little as 25–40 gm. of protein, .4–.6 gm. calcium, and only a few milligrams of

[3] Williams, R. J., *Biochemical Individuality*, John Wiley & Sons, 1956

iron per day, although a surplus over actual body needs is unquestionably desirable in most cases. In times of war or food scarcity, when food must be rationed, the standards for whole populations have been considerably lowered with no apparent physical harm. And in the countries with low economic levels, such as those in Asia, Africa, and South America, it will be fortunate if in time the food supplies can be raised until everyone can secure at least the *minimum* amounts of all nutrients needed for health.

Nutritionists in this country believe that a considerable excess of protein, minerals, and vitamins over actual needs will probably promote better health, but in the case of at least some nutrients, this is by no means proved The British and Canadian standards for vitamin C are only 30 mg per day for adults (10 mg. prevented deficiency symptoms) and people in these countries are pretty healthy, it is not certain that Americans enjoy any better health because of getting 70–75 mg. of this vitamin daily, although this amount is easily obtainable in this country where citrus fruits are plentiful In the case of the fat-soluble vitamins and many of the minerals, there is the advantage in a surplus that body stores can thus be built up (as protection against later possible shortages) but this is not true for the water-soluble vitamins And there may be disadvantages to a continual oversupply of some nutrients In fact, some nutritionists are beginning to question whether over-feeding is not a real problem in this country This is certainly true in respect to calories, since the incidence of overweight is so high, and it is possible as to other nutrients (especially our high consumption of fats)

The recommended allowances are intended to be a help in planning a well balanced diet, which will not be short in any essential nutrient, they should not be regarded as a rigid rule for everyone or as a standard to which the diet must measure up every single day. Slight shortages or surpluses will even up from day to day For instance, on days when leafy vegetables or liver are eaten doubtless more than the daily quota of iron and vitamin A will be furnished, while on days when some other vegetables are served the intake of these nutrients may be lower than standard Hence the rule that green, leafy, or yellow vegetables should be included at least 3–5 times a week. The recommended *dietary pattern* (inclusion of certain food groups in definite amounts each day) should be followed in order to prevent any continued shortage of protein, minerals, or vitamins. The calorie intake should be adjusted to individual needs, as even a slight excess of calories, if long continued, will lead to overweight

QUESTIONS AND PROBLEMS

1 Calculate your own approximate requirement for energy, using figures given in Table 1 (p. 65) for calories required per day for each kilogram of body weight at your degree of muscular activity (convert

weight from pounds to kilograms by dividing by 2.2). If you are overweight, consult tables of average weight for height in Appendix and use figure of normal weight for your height instead of your actual weight Compute your protein allowance by multiplying your weight in kilograms by 1 (1 gm protein for each kg. weight) Consult table of recommended allowances (1958) of the Food and Nutrition Board, given in the Appendix (page 566), to see how much your allowances for energy and protein differ from those given for a person of your sex and degree of activity but of weight specified in the table

2 Make menus for a day that include the kinds and amounts of foods in the "foundation diet" (pp 326–328) Supplement these foods with others in amounts sufficient to bring up the caloric value to your own calorie requirement (as calculated in above problem) and calculate the amount of protein provided by this diet Would it meet your own protein allowance?

3 The Bureau of Home Economics and Human Nutrition has suggested the two sets of menus given below, one suitable for use in the northern and one in the southern portions of the United States Both diets are supposed to supply about 3,000 calories and to be up to the recommended allowances in respect to all essential nutrients, in spite of widely different food patterns.

Menu 1

Breakfast

Orange, 1 medium
Oatmeal, 1 cup, cooked
Milk, 1 cup
Egg, 1
Toast, 3 slices
Butter, 2 pats
Coffee, with cream and sugar

Lunch

Baked beans, 1 cup
Cabbage slaw, ⅔ cup
Boston brown bread, 2 slices
Butter, 1 pat
Peanut cookies, 3 small
Milk, 1 cup

Dinner

Pot roast of beef, med svg (100 gm)
Potatoes, boiled, 2 large
Carrot strips, raw (1 small carrot)
Peas, canned or frozen, ½ cup
Bread, 3 slices
Rice pudding with raisins, ½ cup
Coffee, with cream and sugar

Menu 2

Breakfast

Hominy grits (⅔ cup, dry), with pork gravy
(Or cornmeal pancakes, fat pork, and molasses)
Coffee, with evaporated milk

Lunch

Hot biscuits
Peanut butter, 2 tbsp
Molasses, 3 tbsp
Turnip greens, ½ cup, cooked with fat pork

Dinner

Pork shoulder, med svg (100 gm)
Sweet potatoes, 2 medium
Tomatoes, canned, ½ cup
Black-eyed or cow peas, dried, cooked (⅓ cup, dry)
Buttermilk
Corn bread
Margarine

Using the tables in the Appendix for Nutritive Values of Foods in Average Servings or Common Measures, calculate for each diet how

much it would provide of all essential nutrients (energy, protein, calcium, iron, vitamins A, B_1, B_2, niacin, and C). If necessary work in teams, each taking one nutrient to calculate Where quantities are not specified (cream and sugar in Menu 1, pork fat, biscuits, buttermilk, corn bread, and margarine in Menu 2), use enough of these foods to bring the caloric intake up to 3,000 calories Assuming that these diets are meant for a man of average weight who is physically active, consult the table of recommended dietary allowances in Appendix and compare your figures with allowances given for a man in this category, to see whether the quantities furnished come up to the standard allowances in respect to all essential nutrients In the second diet, which foods are mainly responsible for contributing protein, calcium, iron, vitamins A and C?

SUPPLEMENTARY READING

Cooper, Barber, Mitchell, and Rynberger, Chap 10, NUTRITION IN HEALTH AND DISEASE, "Meal Planning to Meet Recommended Allowances," pp 113–117, 13th ed, *Lippincott, 1958*

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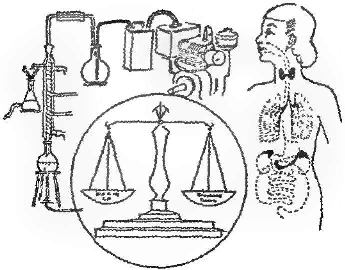
PART TWO

Body Processes



much it would provide of all essential nutrients (energy, protein, calcium, iron, vitamins A, B_1, B_2, niacin, and C). If necessary work in teams, each taking one nutrient to calculate. Where quantities are not specified (cream and sugar in Menu 1, pork fat, biscuits, buttermilk, corn bread, and margarine in Menu 2), use enough of these foods to bring the caloric intake up to 3,000 calories. Assuming that these diets are meant for a man of average weight who is physically active, consult the table of recommended dietary allowances in Appendix and compare your figures with allowances given for a man in this category, to see whether the quantities furnished come up to the standard allowances in respect to all essential nutrients In the second diet, which foods are mainly responsible for contributing protein, calcium, iron, vitamins A and C?

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Wilder, R tary Allowances,"

The Body as a Whole in its Relations to Food

IN THE early textbooks and writings about nutrition, the scope of the subject was almost entirely limited to setting forth what the body needed and how to supply these wants in the food—fuel, material for repair, and regulating materials. If these were supplied in proper amounts in the diet, it might be supposed that the machine would run smoothly for an indefinite period. "Sufficient calories and a balanced diet" was the slogan, and ***nutrition*** was almost synonymous with ***food requirements.*** Now we know that this scheme makes matters look simpler than they really are.

The body is *not* a machine and therein lies the dilemma. If it were, we *could* simply feed in the necessary amounts of various food materials and receive health as the finished product of a perfectly functioning mechanism. But the ***body is a complex living organism.*** Its different parts act and react upon each other in mutual adjustments quite impossible to any machine. Furthermore, the machine is practically unaffected by its

individual who tends to be tall and thin, while another type of person inherits a short and stocky build Brillat-Savarin, a French connoisseur of food and a keen observer, who about 1825 wrote a treatise[1] on "gastronomy" which was the last word on nutrition for that day, noted the "natural predisposition to corpulence" and described this type of person as having "a short face, round eyes, a flat nose, and an amiable, lively disposition" He also described the type that is disposed to leanness as having "an elongated shape, small hands and feet, slender legs and back, prominent ribs, aquiline nose, long face, pointed chin, and brown hair" These excellent descriptions will recall to all of us persons of such builds whom we have known Moreover, we see these same variations in build among the lower animals, e g, the greyhound and the bull dog represent the slender and stocky types among dogs, the race horse and the dray horse (Percheron) show the same contrast in body build in horses

These contrasting types of body build are now a well-recognized biological feature They are often called the *linear* and *lateral* types[2] and due allowance must be made for height, breadth, and depth (thickness from front to back) of body in determining whether the weight is enough over or under normal to cause concern It is normal for the person who inherits long, slender bones and light musculature to have less than average weight, while the broad (lateral) type shows heavier bony framework, relatively more flesh, and above average weight

However, a 10 per cent deduction from the theoretical normal weight for height should be the upper limit of allowance to cover the slighter body build of the linear type, while a 15 per cent extra allowance should be enough to account for normal heavier framework of the lateral type Greater variations than these usually indicate less than optimum nutritional status, with conditions undesirable for health[3]

Sheldon, on the basis of a twenty-year study of young men at Chicago and Harvard Universities, has confirmed the existence of variations in body measurements and temperament that fit previous descriptions of the slender and stocky types, and has postulated a third class, the muscular or athletic type[4] The athletic type may be briefly described as having a square face (contrasting with the round and oval faces of the stocky and slender types), broad square shoulders, heavily developed muscles, and an aggressive, insensitive disposition, with a love of action and power The slender type is sensitive, shy and introspective The stocky type is comfortable, cordial to people, self-indulgent,

environment, whereas the human body is played upon by many different stimuli from without, and by thoughts and emotions from within.

In recent years we have been forced to face the problem that food is not all there is to nutrition by finding an increasing number of persons who are receiving plenty of good food but who nevertheless are not properly nourished. They may be either over or under nourished, either carrying about a burden of excessive fat or too thin, with low vitality and endurance, or they may be normal in weight but under par in health. Gradually we are coming to realize that nutrition should be considered from the standpoint of the *body as a whole in its relations to food.* We cannot talk of one food as being wholesome and another unwholesome without taking into account the relative conditions of the individual when the two foods were eaten, we cannot speak of the stomach and the processes going on in it as if they were independent of the rest of the body, we cannot build a healthy body as a result of taking an adequate diet, when the food is eaten under conditions of habitual strain and overfatigue. In a hundred different ways nutrition is affected by interrelations between food and the body, between the different parts of the body, and between the body and its environment.

In short, there are *two* main aspects of nutrition—*the food intake* and *what the body does with it,* and the second of these is as important as the first, since the condition of the person who receives the food determines how much or how little he is able to profit by it.

In view of this broader meaning of nutrition, it seems advisable to take up in this chapter some of the more *general factors* which are directly or indirectly *concerned in the nourishment of the individual.* The vital importance of taking these factors into consideration when one attempts to rebuild the health of malnourished persons has been established by successful application

GENERAL FACTORS WHICH INFLUENCE NUTRITION

The general factors which exert an influence on the nutritional state of the body may be listed as follows:

(1) Type of individual
(2) Physical defects
(3) Postural defects
(4) Overfatigue
(5) Mental and social factors
(6) Habits
  (a) General health habits
  (b) Food habits

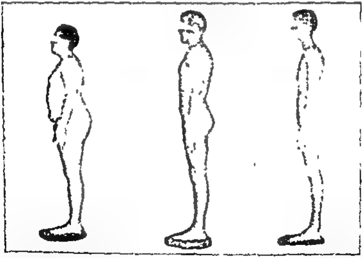
Type of Individual

There is nothing new under the sun and it has long been recognized, even by casual observers of the humar

blood. This in turn may lead to poor nourishment and decreased vitality of the tissues, so that this type is often susceptible to chronic fatigue, colds and other respiratory infections, as well as anemia and nervous indigestion The digestive tract is muscularly active and the small intestine is shorter and more easily irritated than in other types of individual, food passes along more rapidly and assimilation is relatively poor. Hence, it is difficult for such persons to put on weight and they need a *more highly concentrated, nutritious and well cooked diet.* Persons of slender build are often finicky about food, dislike "roughage," get hungry at shorter intervals but are satisfied with less bulk than other types They may get on better with four or five small meals than with two or three large ones

The muscular or *athletic type* has a hearty appetite and usually exercises enough to have fairly high energy needs Such individuals have steady nerves, good circulation and digestion, they can eat almost any food but usually eat in hurried, business-like fashion, and may overeat on certain foods, especially meats Sheldon states that this type is especially prone to develop appendicitis, sinus infection, cancer, infantile paralysis, and sometimes gastric ulcer (seen more frequently in the slender type).

The *stocky type* has a capacious chest, good circulation and aeration of the blood, the "digestion of a billy-goat," and love of eating The excess weight which they so often accumulate puts extra strain on vital organs, and it is common knowledge that this type is particularly sub-



A B C

Figure 108 Side views of three extremes in type of body build A, stocky or lateral type, *B*, muscular or athletic type, *C*, slender or linear type. (Sheldon and Stevens, THE VARIETIES OF TEMPERAMENT, Harper & Bros)

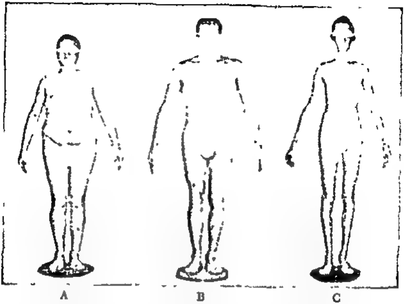


Figure 107 Front views of three extremes in type of body build. *A*, stocky or lateral type, *B*, muscular or athletic type, *C*, slender or lineal type (Sheldon and Stevens, THE VARIETIES OF TEMPERAMENT, Harper & Bros)

and averse to physical activity. Sheldon's classification is based on which of the three layers of the embryo developed predominantly. In the slender type there is predominance of brain and nervous tissues that arise from the outermost layer of the embryo, in the athletic type the predominant development is in body framework and muscles, parts that develop from the middle embryonic layer, in the stocky type the "gut" and other internal organs, which arise from the inner embryonic layer, are predominant Of course there are many variations or intermediate grades of body type, pure types are relatively rare, and mixed types are common.

It is now well recognized that these types also involve inherited variations from the normal in the size, shape, and position of the different parts and organs of the body, which may determine their functioning in such a way as to offer at least partial explanation of the tendencies toward overweight or underweight, and toward certain diseases.[5] Modern "somatic" medicine stresses the necessity of considering the body as a whole in the cure and prevention of disease

FUNCTIONAL SIGNIFICANCE OF BODY TYPES. In the *slender type*, the long, narrow, shallow chest cavity and flabby diaphragm make for shallow breathing, poor circulation, and less efficient oxygenation of the

[5] Thompson, M , "On Anatomical Types and Their Relationship to Disease," Canad M J , *14*, *1155*, 1924, Draper, G , *et al* , "Studies in Human Constitution," J A M A , 82, 431, 1924, and Am J M. Sc , 169, 322, 1925, Goldthwait, J. E , *et al* , BODY MECHANICS, Lippincott, 1934, and Sheldon, W. H , *et al*, THE VARIETIES OF HUMAN PHYSIQUE, Harper & Bros , 1940.

cramped position and supported by a low and flabby diaphragm muscle so that breathing is shallow, than a chest of lesser capacity which is used with maximum efficiency. A *stomach* which is capable of doing its job well when in normal position may give constant trouble when it has sagged so far down in the abdomen that its contents must be emptied against gravity or its blood and nerve supply are interfered with. An *intestine* which formerly functioned well may lose the good tone of its muscle wall when there is habitual stagnation of its blood supply, due to its position in the abdomen and to the inactivity of the diaphragm, which is largely responsible for "milking" the blood out of the abdomen back toward the heart by its rhythmic contractions in breathing.

These few illustrations, which will suffice to point out how it is impossible for an organ to do its work efficiently when held in a disadvantageous position, have been selected because of the evident *influence* of the poor functioning of these particular organs *upon nutrition.* But no tissue or organ can work well and remain healthy when it is habitually

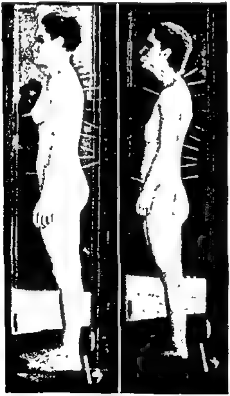


Figure 100 Photographs showing good and poor posture (Courtesy of Department of Physical Education, Teachers College, Columbia University.)

ject to high blood pressure, apoplexy, and diseases of the heart, kidneys, liver, and gallbladder, as well as diabetes. They will put on weight sometimes on a smaller amount of food than suffices to maintain weight in the slender individual Due to the longer time which the food requires for passage through a long, rather sluggish intestine, the absorption of the digested food elements is unusually complete. The stocky type, therefore, needs a more *bulky diet* and one *not concentrated in its caloric value,* in order to avoid taking on excessive weight.

Physical Defects and Their Influence on Nutrition

Physical defects have a relation to nutrition only when they interfere in some way with one or more of the vital body processes. Thus *growths in the nose and throat,* which obstruct *breathing,* are a prominent factor in producing malnutrition, especially in young children when the air passages are smaller, as oxygen from the air is necessary for nutrition of the tissues. Obstructions in the throat may also interfere with *swallowing,* and *tooth defects* may cause the food to be insufficiently *chewed.* Another cause of decreased vitality and inability to gain weight may be bacterial infection (usually mild and chronic) in one or more parts of the body Such conditions as diseased tonsils, sinuses, or decayed teeth have an influence on the body as a whole and must be cleared up before the best condition of health can be attained.

Postural Defects and Their Influence on Nutrition

The way the body is used may be as important as the structure of the body itself. By this we mean the more habitual postures in which it is held or carried. The body should be carried so that the center of gravity is well balanced, an erect posture is maintained without undue effort, and muscles are not kept under stress or strain. In action, the posture should be one that makes for efficient performance of muscular work with minimum of fatigue Postural defects that are commonly seen (most frequently in persons of slender build) are (1) head too far forward, (2) chest flat, (3) abdomen relaxed and prominent, (4) back curves exaggerated [6] Although authorities now allow more leeway in what is considered good postural position, they agree that, for any given individual, the ideal posture should be one that makes for at least moderately good appearance, freedom of action, lack of strain on muscles, ligaments, and joints, and proper functioning of the internal organs

Bad posture may put certain parts of the body under *strain* or *cramp* them so that the blood supply to them is poor and they are unable to do their work effectively. A deep *chest* of potentially large air capacity may actually produce poorer aeration of the blood, if held in a

[6] Although there are a number of other types of defective posture, it seems best to limit the discussion here to fatigue posture, which is by far the most common type and the one which is directly associated with malnutrition.

ulated so as not to realize that its energies are being exhausted, and pride in its achievements may cause the parents to spur on rather than to restrain

With *adults* the same factors operate to produce fatigue, the most active ones being *worry* and fretfulness, *lack of rest periods, overdoing at work or play*, and inadequate vacations or weekly rest Again the individual may be sufficiently "keyed-up" not to realize his fatigue or he may have the feeling of being all dragged out but keep on by exertion of will power or by taking stimulants such as coffee, alcoholic drinks, or "pep-up" drugs

However, in any such discussion we must distinguish clearly between *fatigue*, which is the natural by-product of proper and necessary exertions, and *overfatigue* which means exhaustion—especially *habitual overfatigue*, which carries a person farther and farther from his normal state of health and makes his recovery more difficult

What is the proof of any direct *relationship between overfatigue and nutrition*? First an overfatigued individual usually experiences a *loss of appetite* or shows a capriciousness of appetite and taste in foods, which makes it very difficult to give either sufficient food, a well-balanced diet, or food at proper intervals and in regulated amounts Not only is there little desire for food, but what is eaten is apt to disagree We know beyond a doubt that the *ability to digest* and absorb food is *lessened* by unfavorable nervous conditions—in fact *physical fatigue*, as well as *nervous fatigue*, may cause digestion to be markedly slowed down

But the most convincing proof that overfatigue is a significant influence in nutrition lies in the fact that most overfatigued individuals are *underweight* and persistently fail to gain until this condition is relieved by extra rest periods The decreased weight is accompanied by *weakness, susceptibility to infections, nervous irritability*, and other signs that the vitality of the tissues is lowered by their being chronically undernourished

Mental and Social Factors

It is not necessary to go into any discussion of mental and social factors, but they do need to be mentioned, since the fact that happiness has a positive health value, while undesirable mental states lead to many physical ills, is frequently overlooked or underestimated by both physicians and laymen These factors, when unfavorable, may exert a strong *influence on nutrition* by acting to cause *loss of appetite and weight* and *disturbed functioning of the digestive organs*, in the same manner as outlined in the paragraph above for fatigue Favorable effects upon digestion and nutrition will result if good social and mental states can be substituted for the bad Social forces center about the home, school, business and social life, while mental factors are largely under one's own control In this day of high-pressure living, conscious effort is often

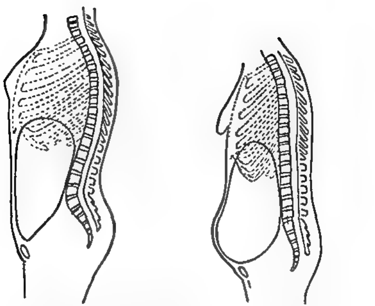


Figure 110 A, diagram showing body held in normal position with chest elevated and abdominal cavity shaped like pear with large end uppermost B, diagram showing how flat chest and drooping ribs maintained in poor posture assist in forcing viscera down until the shape of the abdominal cavity is the reverse of the normal, smaller at the top (Courtesy of Williams and the Boston Medical and Surgical Journal)

placed under such conditions that its blood supply is interfered with or that it is working under strain.

Overfatigue

After more than twenty years of work with underweight children and adults in nutrition classes and clinics, Dr. Emerson made this statement, "Continued experience in the treatment of malnutrition leads me to the belief that there is no responsible cause for this condition more frequently overlooked than habitual overfatigue."[7] In a large group of *malnourished children* under his observation he found that 64 per cent kept late hours and 54 per cent were suffering from overfatigue due to *extra work in clubs, classes, or industry*[8] *The strain of keeping up school* work, competitive games, ordinary play, or parties is seldom realized Rest periods are not provided during the day nor sufficient restful sleep insisted on at night Unhappy home conditions sometimes augment nervous fatigue. It is thus difficult, if not impossible, to separate mental and social factors from the problem of overfatigue. Adults do not appreciate how many and wearying are the activities of a child and how much of its energy is required in growth. The child may be overstim-

[7] Emerson, W R P., NUTRITION AND GROWTH IN CHILDREN, p 80 Appleton, 1922
[8] Ibid, p 58

Boys [redacted] to 14 years of age were found to be 6–8 per cent taller and 12–15 per cent heavier than fifty years ago [12] The probable causes are suggested to be better nutrition in infancy and childhood, fewer communicable diseases, higher living standards, and more widespread information about nutrition and health.

Connection between Weight and Health

The most convincing evidence of the relation of weight to health is the *correlation of overweight and underweight with higher mortality figures* in the statistics gathered by life insurance companies. Tables have been published showing the *average* weight for the various heights, with age, sex, and in some cases type of body build, also being taken into consideration (Such tables are given in the Appendix.) As these figures have been compiled from groups which include a rather high percentage of underweight children and young adults, and of overweight individuals in the age groups after forty, they do not represent the normal or *ideal* weights The most recent table as to what are considered "ideal" weights for heights, irrespective of age, was given on page 84 This table also makes variations for different body builds

In youth a weight slightly in excess of the ***average*** figures given in the tables (5–15 per cent higher) is considered ***advantageous,*** as providing a factor of safety to be drawn on in case of need (growth, sickness, or temporary food insufficiency) and promoting *greater nervous stability, increased vitality,* and *higher resistance to infectious diseases* (tuberculosis, pneumonia, etc) Life insurance figures have shown that *in the early twenties mortality increases about 1 per cent for each pound below average weight* for height

Overweight also is ***disadvantageous*** for health, ***especially in the later years.*** The tissues of fat people are not properly nourished so that they are notoriously poor risks in operations and infectious diseases, the excessive weight places an additional burden upon the circulatory system and kidneys, so that such persons are prone to develop functional disorders of the heart, high blood pressure, nephritis, etc. *Above the age of thirty-five, mortality increases about 1 per cent for every pound over normal weight* for height

Thus we see that conditions where the nutrition has been badly carried out (underweight and overweight) are directly associated with poor health and lowered vitality It means a better chance of life and health if one can so adjust his food intake, surroundings, and habits of life as to attain and keep himself at the optimum weight for his height

It is quite possible to maintain an excellent state of nutrition in persons of all types of body build and in almost any environment, but to do so *special consideration will often need to be given to the factors outlined in this chapter.* We should recognize the importance of these

[12] Meredith, H V, J Am Dis Child, 62, 909, 1941

necessary to secure the right relations with one's self and one's fellows Hence it may not be out of the way to append a list of a few of the most unfavorable factors of this kind, contrasted with their pleasant and beneficial opposites, so that one who desires may check his own tendencies.

Negative	Positive
Fear	Confidence
Envy and discontent	Contentment
Strong dislikes	Affections
Hurry	Leisure
Worry	Hopefulness
Irritability	Tranquillity
Self-interest	Interests outside of one's self
Self-indulgence	Self-control

Habits

It is generally recognized that habits of living have some influence on health, but probably it is seldom realized how strong this influence may be. In a malnourished individual a number of bad food and health habits are generally to be found by questioning The general health and food habits should be carefully surveyed and good habits substituted for bad, before the undernourished person will be in a position to get maximum profit from an improved diet and thus attain his highest standard of well-being.

The more *common faulty habits,* as found in surveys of food and health habits of both children and college students,[9] are *late bedtime, insufficient exercise* and *outdoor life, irregular bowel movements,* use of *tea* and *coffee* by children, *eating too fast or when overfatigued,* and *indulgence in sweets* between meals. The students who were underweight and those who had frequent colds showed a higher percentage of poor health habits, while a group of students of superior ability had fewer illnesses than the average.

This does not mean that college students generally are in poor health or nutritive condition. Most of those studied were of normal weight (or above), with few ailments except occasional colds, and with excellent appetites—in fact, the majority ate between meals The present-day college student is both taller and heavier than those of thirty or forty years ago,[10] and college men are apparently of greater average height than men of the same age group in the population as a whole.[11]

[9] Emerson, W R P, "Health Habits in a Women's College," J A M A, 90, 1434,

Home Econ, 40, 19, 1948

[10] Chenoweth, L B, J A M A, 108, 354, 1937.

[11] Diehl, H S, Human Biol, 5, 445, 1933.

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supplementary factors in nutrition and stress the need of replacing any existing unfavorable factors with those that are favorable for health.

QUESTIONS AND PROBLEMS

1. Check your weight with the average weight for your height and age (see weight tables in Appendix). Compute the per cent deviation from the average as follows: divide the difference between actual and average weights by the average weight and multiply by 100. Now check with the table on page 84 to see what weight is considered "ideal" for your height and type of body build If your weight is not what it should be, according to these standards, suggest any reasons for this weight deviation from normal and any changes in diet that may need to be made.

2. Score your general nutritive condition by comparison with the following standards for good nutrition of whole body:

Skin—turgid, smooth, slightly moist, and of healthy color.
Eyes—clear, no dark circles underneath, hair—smooth and lustrous.
Muscles—well developed and firm, not flabby.
Mucous membranes of eyelids and mouth—reddish pink
Posture, good—head erect, chest up, shoulders flat, abdomen in, body well balanced
Sleep, appetite, digestion, and elimination—good.
Freedom from easy fatigue and susceptibility to infections

3. Check your food and health habits by noting whether you have any (or how many) of the following faulty habits.

General	Food
Irregular bedtime	Irregular mealtimes
Irregular bowel movements	Omitting breakfast
Insufficient exercise and time outdoors	Finicky about food
	Habitual overeating or undereating
Insufficient rest periods	Fast eating or washing food down
Excessive tea, coffee, tobacco or other stimulants	Eating when overtired
	Eating between meals, especially sweets

4. A young woman, 18 years old, is 12 per cent underweight, has teeth that decay readily and diseased tonsils, is nervous and tires easily, has frequent colds She has been dieting moderately to keep down weight, avoids fatty foods and takes little bread and butter or milk, likes meat, eggs, and fruit, but dislikes vegetables and salads What measures are needed and what changes in living habits and diet should be recommended in order to increase her weight and build up her general nutritive condition?

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Digestion and Absorption of Food

DIGESTION

Why Digestion Is Necessary

Digestion, which takes place in a series of organs known collectively as the alimentary tract, is the *process by which food is prepared for absorption* into the body proper. As eaten, most of the *food materials* are in the form of complex substances, which are either *insoluble* in water *or of such a nature that they cannot diffuse through the membranes* that line the digestive organs, and hence cannot be absorbed into the blood.

Moreover, even if the material could get through the intestinal lining and into the blood stream, the *tissues could make no use of these complex substances,* since the cells are so constituted that they use in their life processes only much simpler substances. Starch and the more complex sugars, it will be remembered, are all compounds made by linking together simple sugars (p. 21); proteins are complex substances formed

by linking together amino acids (p 34), fats are made by the combination of fatty acids with the simple substance glycerol The business of digestion is chiefly concerned with breaking down these three classes of foodstuffs into their "building stones," i e, into simple *sugars, amino acids, fatty acids* and *glycerol,* which are the ***simple,*** standardized forms in which ***food materials*** are ***usable by the tissues,*** either as body fuel or for tissue building

The Alimentary Tract

The alimentary tract will be best understood if it is considered as organized for its two sets of functions namely, its ***muscular*** or motor apparatus, and its ***glandular*** apparatus The first has the task of mixing the food mass with digestive juices and moving along partially digested material from one part of the alimentary tract to another The second has the function of secreting the important digestive fluids which are responsible for bringing about the chemical break-down of foodstuffs The arrangement of the various organs in series (mouth, esophagus, stomach, small intestine, large intestine) is familiar to almost everyone This arrangement of the digestive organs forms a continuous hollow tube (sometimes called the alimentary canal), with widenings in certain sections (stomach, large intestine or colon) which act as reservoirs where

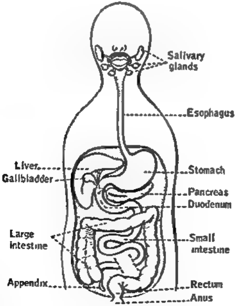

Figure 111 The alimentary canal and glands which secrete the digestive fluids The small intestine is much longer than can be shown in the diagram (indicated by break and dotted lines) and lies in many coils in the abdominal cavity

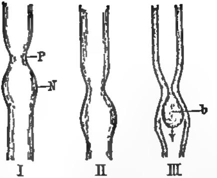

Figure 112 Exaggerated representation of peristalsis. I and II are successive views of the same portion of the alimentary tube, the zone of contraction (*P*) shifting downward and always preceded by the zone of unusual relaxation (*N*) III is an imaginary section through II, showing the food bolus (*b*) slipping along in advance of the contracting region, its advance being facilitated by the relaxation below. (Stiles, NUTRITIONAL PHYSIOLOGY)

the contents may be held for longer periods A diagram of the alimentary tract and glands which secrete digestive fluids into it is given in Figure 111

It should be borne in mind that the digestive tract *operates*, somewhat like a railway system, *by means of signals sent on ahead* from one organ to the next in the series to prepare the way for the oncoming load Hence, when conditions are such that digestion gets a good start, the later stages go on more smoothly, whereas anything that affects the earlier stages of digestion unfavorably may result in slowing of or discomfort in the later stages

The *muscular apparatus* concerned in digestion may be briefly described as follows First there are the muscles of the jaws and tongue which function in the acts of chewing and swallowing, but more important are the muscular coats of the stomach and intestines by which the movements of these organs are carried out. The structure of the walls of the alimentary "canal" is essentially similar throughout its whole length—a so-called "*mucous membrane*" lining the cavity, two coats of *muscular tissue*, one consisting of *circular* and one of *longitudinal* muscle fibers, and a very thin membrane covering the outside of the tube

When the circular muscle fibers contract, as they do in small, separate segments, they exert a squeezing motion which presses the contents of the tube closely against its inner wall, churns them about and divides them into separate segments. When the longitudinal muscle fibers contract, the resulting motion pushes the food mass in one direction or another along the digestive tract. These contractions occur in regular waves that pass along the tube almost always in such a way as to propel the food ahead, i e, toward the lower end of the tube, the rectum and its outlet, the anus Such rhythmic, recurring waves of contraction are spoken of as ***peristalsis.*** In a few parts of the alimentary canal these

waves of contraction in the muscle coat may travel in the opposite direction, so that they push the food backward in the tube, in this case the term *antiperistalsis* is applied to them Emotional or digestive upsets *may sometimes bring about antiperistaltic waves, resulting in vomiting.*

The stomach has a slightly more complex system of muscular coats, in which there are diagonal as well as circular and longitudinal fibers, so that its movements are more varied though similar in general to the movements of the intestines. Active peristaltic waves begin about the middle of the stomach and travel downward The esophagus and upper part of the stomach have less marked muscular coats and are relatively inactive muscularly.

The glands which function *in secreting* the *digestive fluids* are of two kinds—very small, *simple glands* situated in the "*mucosa*," or mucous membrane that lines the alimentary tract, and more *complex glands* located *outside the digestive tract* but which pour their secretions into it through ducts The structure of all of them is essentially similar and is shown *in its simplest form in the diagram given in* Figure 113 The lower part of the picture shows the blood supply to the gland, which is essential for bringing to it the materials from which the secreting cells (those lining the pocket-like depression of the gland) manufacture the special substances peculiar to the secretions of that gland. Compound glands are made up of larger numbers of simple glands, bound together

Figure 113 The principle of glandular structure (Top) A simple microscopic gland supposedly laid open by a section along its vertical axis The cells are seen to surround a recess into which they discharge their secretion (Bottom) The same structure shown in its entirety, and in addition the encircling blood vessels which contribute to make good the losses suffered by the secreting cells (Stiles, NUTRITIONAL PHYSIOLOGY)

with connective tissue and blood vessels, whose individual ducts converge so as to form a system of passageways toward the single main duct The *salivary glands, pancreas,* and *liver* are compound glands, which secrete digestive fluids (the *saliva, pancreatic juice,* and *bile*) that are discharged into the alimentary tract. *Simple glands, located in the membrane lining the stomach and small intestine,* secrete the digestive fluids known as the *gastric juice* and *intestinal juice,* respectively Other simple glands, found in the mucous membrane throughout the whole course of the alimentary tract, secrete a slimy substance called *mucus,* which has no digestive powers, but serves to lubricate and protect the lining membrane, as well as to give it its name.

Progress of Food Material Through Digestive Organs

In the *mouth,* the food is more or less finely divided by *chewing* and is mixed with saliva, which moistens the food and also exerts a chemical action, and with mucus that assists in lubricating the food for swallowing. The swallowed food mass is carried down the esophagus by a muscular movement, a wave of relaxation preceding the food and a wave of contraction following it (see Figure 112, page 354).

In the *stomach,* the swallowed food collects largely in the muscularly inactive upper part (cardiac end) which acts as a reservoir where food may remain for some time before it is gradually pushed along toward the outlet end (pyloric portion) The cone-shaped portion of the stomach adjoining the pylorus (a circular muscle that guards the opening into the intestine) is muscularly active, and in its wall are situated the glands that secrete the digestive fluid, gastric juice Here the food mass is mixed with gastric juice and churned about until (partly by mechanical means and partly by action of the digestive fluid) it is reduced to a semiliquid state (chyme) From time to time the pylorus opens and a peristaltic wave sends a gush of the more fluid portion of the stomach contents into the first part of the intestine (duodenum), and thus the stomach is gradually emptied. As it empties, the stomach contracts upon itself, so that it is relatively small and usually contains only a little fluid between meals The rate at which the stomach empties is chiefly dependent on the type of foods that comprise the meal *Liquids* leave the stomach relatively *quickly,* carbohydrates tend to pass out faster than proteins, and proteins faster *than fats, mixtures of proteins and fats leave the stomach* more *slowly than either alone.*

The healthy stomach will usually empty in 1½ to [illegible] hours, depending on the quantity and nature of the meal taken The average time for the stomach to discharge an ordinary meal is 3 to 4 hours. Meals should be spaced so as to allow an intervening brief rest period for the stomach (usually 4 to 5 hours is a good interval). If the stomach is empty for too long a period, strong rhythmic contractions, known as *hunger contrac-*

tions, set in Some persons develop hunger contractions more readily than others and may need to be fed smaller meals at shorter intervals. On the other hand, acute gastric distress is sometimes caused by a meal that fails to pass on out of the stomach as it should, usually such a disturbing meal will be found to have been one rich in fats or mixtures of fat with protein (pork, cheese, etc). However, the inclusion of some fat in a meal is useful, when the desire is to have the meal "stay by one" so as to prevent hunger contractions before the next mealtime.

Food material which has been passed on from the stomach into the *duodenum* is allowed to remain there until it is well mixed with the digestive juices poured in at that point, and is then gradually pushed along into lower portions of the intestine by peristaltic contractions and by further discharges from the stomach In the *small intestine*, the largest part of the processes of digestion and absorption take place These processes are aided by contractions of the intestinal muscles—those of the circular muscle fibers, which divide into intestinal segments, thus mixing the contents thoroughly and squeezing them against the intestinal walls, and those of the longitudinal fibers, whose wavelike movements (peristalsis) gradually pass the intestinal contents along toward the

Figure 114 Shadows of the human stomach obtained with the aid of the roentgen rays 15 minutes, 1 hour, and 4 hours after ingestion of the bismuth meal (Burton-Opitz)

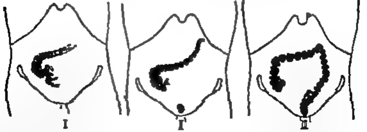

Figure 115 Shadows of the human large intestine obtained with the aid of roentgen rays at later intervals after the bismuth meal (I and II) and after injection of a solution of bismuth salt through the rectum (III) (Burton-Opitz.)

opening into the large intestine. By the time the outlet to the large intestine is reached, digestible material is usually about *85 per cent digested and absorbed* The length of time that is required for food material to pass along the small intestine will vary with the relative muscular activity of that organ in various persons, irritating substances within the intestine (as well as some cathartics) will stimulate peristalsis and are the usual cause of diarrhea, a condition in which food residues pass through the intestines so quickly as to be excreted in fluid condition

The *large intestine* has about twice the diameter of the small intestine but is much shorter and less muscularly active It acts as a reservoir in which food residues stay for some time and are concentrated by absorption of water, and from which they are finally passed into the rectum From the rectum, they are passed at intervals to the exterior through the anus, an opening guarded by a double ring of circular muscle fibers. The peculiar position of the colon (see Figure 115) also favors longer retention of food residues (ascending, transverse, and descending *portions*). *Food residues and excretory material often remain in the colon* 18 hours or more, and conditions for bacteria to grow are more favorable here than in any other part of the alimentary tract. Hence the muscular activity of the colon is important in maintaining intestinal hygiene, and factors that tend to favor moderately rapid passage of material through this section of the alimentary tract are usually beneficial to health

Chemical Processes in Digestion

The chemical processes, by which the *foodstuffs* are actually *broken down* in preparation for their *absorption and use by the tissues,* really *constitute digestion* in the narrower and more correct use of the term

Digestion takes place through a *cleavage* of the complex food materials into their *simplest component parts.* In the case of very *complex substances* like the proteins and starch, this chemical breaking down takes place *gradually,* so that a good many *intermediate compounds* are formed in the process of digestion before the original material is reduced to its simplest components The long chains of glucose radicals which constitute *starch* molecules are gradually broken down by the splitting off of two sugar groups at a time (maltose molecules), the intermediate compounds being dextrins with smaller-sized molecules, eventually the dextrins are completely converted to maltose and the maltose is broken down into the simple sugar, *glucose* (see Fig 116). The very large molecules of *proteins* are likewise broken down in orderly fashion into those of gradually decreasing size (proteoses, peptones, polypeptids, tripeptids, dipeptids) until they are completely reduced to those *amino acids* from which they were originally built (as shown diagrammatically in Fig 117, page 360)

Fats, although they have molecules much smaller and simpler than those of starch and protein and are acted upon by only one enzyme, are

probably broken down in a series of steps, rather than by a single step as formerly thought The fatty acids are digested off one at a time, forming di- and monoglycerides as intermediate products, but finally most are reduced to *fatty acids* and *glycerol*

The *double sugars* (cane sugar, milk sugar, and maltose) are broken up at a single step into their components—the simple sugars (glucose, fructose, and galactose) The simplest constituents of the diet do not need to be broken down by digestion This is true of simple sugars, mineral salts, meat extractives, alcohol, and water, which are absorbed in the form in which they are consumed

The gradual chemical break-down of proteins and of starch through various intermediate stages until they are finally reduced to their simplest "building stones," and the simpler cleavage of fats and double sugars into their components during digestion, are summarized in word form on p 360 It should be understood that the arrow, in each instance, represents the splitting of a larger molecule into a number of (in some cases very many) smaller ones by means of a chemical reaction with water—a process known as *hydrolysis*

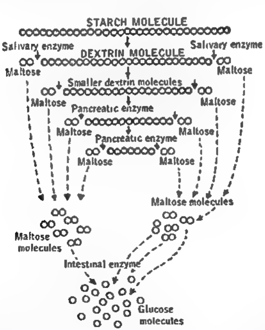

Figure 116 Gradual breaking down of large starch molecules by enzymes in digestion The disaccharide maltose is split off by enzymes in the saliva and pancreatic juice, with smaller and smaller dextrin molecules as intermediate products, until the starch has been completely reduced to maltose An intestinal enzyme then acts on the maltose molecules, splitting them into molecules of the monosaccharide or simple sugar, glucose

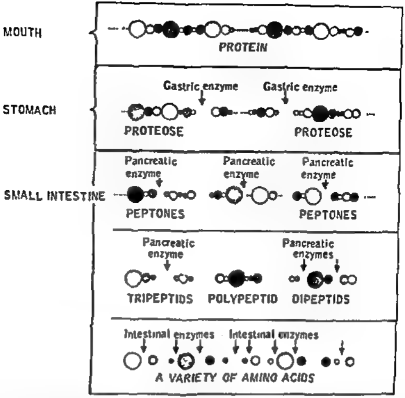

Figure 117 Gradual breaking down of the large molecules of protein into their constituent amino acids during digestion, with proteoses, peptones and peptids as intermediate products The molecules of protein, proteose and peptone are too large to be portrayed in the diagram above by more than small segments (as indicated by the dotted lines) but those of the smaller peptids (di- and tripeptids) are given in *entirety*. When digestion is complete, each huge protein molecule has been completely broken down into the different amino acids of which it was composed.

$$\text{Proteins} \rightarrow \left\{\begin{matrix}\text{acid proteins}\\ \text{alkali proteins}\end{matrix}\right\} \rightarrow \text{proteoses} \rightarrow \text{peptones} \rightarrow \text{peptids} \rightarrow \text{amino acids}$$

Starch → dextrins → maltose → glucose
Fats → fatty acids and glycerol

$$\left.\begin{matrix}\text{Maltose (malt sugar)} \rightarrow \text{glucose and glucose}\\ \text{Sucrose (cane sugar)} \rightarrow \text{glucose and fructose}\\ \text{Lactose (milk sugar)} \rightarrow \text{glucose and galactose}\end{matrix}\right\}\text{simple sugars}$$

Digestive Enzymes

These *chemical cleavages which constitute digestion are brought about through* the agency of substances called *enzymes.* The same chemical changes will take place if proteins, starch, fats, or double sugars are subjected to prolonged heating with water and acid or alkali in the laboratory. The acid or alkali acts as a "catalyst," that is, an agent that speeds up the chemical change merely by its presence. In the body, digestive enzymes bring about *these chemical changes more* rapidly and

at lower temperatures than other catalysts mentioned above They do not themselves take part in the chemical processes by which foodstuffs are broken down but their presence facilitates or hastens these processes. Enzymes are catalysts that are *formed by living cells*[1] and the *digestive enzymes* are formed by the secreting cells of the *digestive glands*, those glands which secrete fluids into the alimentary tract

Enzymes, when they have been separated in pure, crystalline form, have been shown to be typical *proteins* in chemical nature, although of relatively small molecular size There is every reason to belive that they are formed in the body from the amino acids brought to cells by the blood It is noteworthy that their enzyme activity is lost if they are exposed to any chemical that renders protein insoluble, or to a degree of heat sufficient to coagulate protein. All enzymes are sensitive to heat and cold, they are destroyed by boiling temperatures and their activity is suspended by cold The *digestive* enzymes all seem to work best at about the *temperature of the body*

Enzymes are said to be *specific* in that each one acts only upon a certain type of substance and brings about only one special chemical reaction Thus, when a digestive fluid has the ability to act upon two or more kinds of foodstuffs, we know that there must be *separate* and distinct enzymes in it for the performance of each of these chemical tasks.

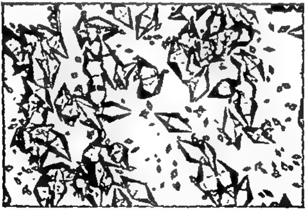

Figure 118 Photomicrograph of pepsin crystals (Northrop)

[1] Enzymes are formed in both plant and animal tissue cells and can facilitate many different types of chemical changes—oxidation, reduction, transfer of some chemical group from one compound to another, splitting off of the amino or carboxy radicals, etc Some, such as the digestive enzymes, catalyze reactions by which compounds are split by reaction with water (hydrolysis) Practically all chemical reactions in body tissues take place through the action of enzymes We have seen that enzymes and coenzymes, in which various vitamins are incorporated, catalyze the important oxidation-reduction reactions in tissues by means of which fuel foodstuffs yield energy for the body Since (as catalysts) they are not used up in the reaction they bring about, a small amount of enzyme will act on a large amount of substance even at high dilutions.

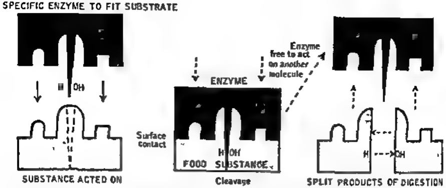

Figure 119 Diagram to explain the fact that an enzyme will act only on one specific substance The idea is that in some way the surfaces of the enzyme and substance acted on (substrate) must fit together or contain chemical groups that are attracted to each other The reaction represented here is that of a digestive enzyme splitting a food substance by hydrolysis (reaction with water)

Nor are the enzymes in different digestive juices that act upon the same kind of foodstuff identical, we know this because they require different *working conditions* The enzyme in the gastric juice that acts on protein requires quite a high degree of acidity to be effective, whereas there is a protein-splitting enzyme in the pancreatic juice that works well in either a slightly acid or even an alkaline medium Each of the digestive enzymes has some degree of acidity or alkalinity at which it works best (called the optimum reaction), and a certain *range of reaction* outside of which it will not work at all. A prominent example of this is the starch-splitting enzyme in saliva, which will act only in neutral or slightly alkaline reaction such as is found in the mouth and in the stomach before the food material is mixed with the acid gastric juice, as soon as the reaction in the stomach becomes acid, the digestive activity of this enzyme is stopped

In addition to optimum temperature and reaction, two other conditions favor the action of digestive enzymes One is good *surface contact* with the substance acted upon, for this reason intimate mixing of digestive juices with finely divided food material and getting the food material ultimately into solution or colloidal dispersion (as with fats) are important. So also is the *removal of the products* formed by the reaction; hence it is only in the small intestine, where the products of digestion are continuously removed by absorption, that conditions are favorable for digestive processes to run to completion, i e, for complete conversion of foodstuffs to their simplest constituents.

Enzymes are usually *named* to indicate the substances upon which they act (called the substrate). To this substrate root is added the suffix *-ase*, which indicates that it is an enzyme, and often an adjective is prefixed to show the source of the enzyme Thus, all protein-splitting enzymes are called ***proteases;*** fat-splitting enzymes are ***lipases*** (from the

Table 18. Summary of Digestion

	Material Acted On	*Enzyme Acting*	*Products Formed*	*Absorbed*
In *mouth* (continuing for time in stomach)	Starch	Ptyalin (salivary amylase)	Dextrins Maltose	
In *stomach*	Proteins	Pepsin (gastric protease)	Proteoses Peptones	
	Casein in milk	Rennin	Precipitates Ca paracaseinate	
	Emulsified fats	Gastric lipase	Glycerol Fatty acids (small amts)	
In *intestine*	Proteins Proteoses Peptones	Trypsin Chymotrypsin	Polypeptides Dipeptides	
	Polypeptides Dipeptides	Erepsin (3 enzymes—carboxypeptidase, aminopeptidase, and dipeptidase)	Amino acids →	In blood to liver
	Starch Dextrins	Amylopsin (pancreatic amylase)	Maltose	
	Maltose	Maltase (intestinal juice)	Glucose →	In blood to liver
	Sucrose	Sucrase (intestinal juice)	Glucose Fructose →	In blood to liver
	Lactose	Lactase (intestinal juice)	Glucose Galactose →	In blood to liver
	Fats	Steapsin (pancreatic lipase)	Simple glycerides Fatty acids Glycerol →	Mostly in lymph Small amts in blood

word lipins for fats), and starch-splitting enzymes are *amylases* (from the classical name amylum for starch) Of course we have to distinguish between the different enzymes that act on the same type of foodstuff, and this is done by means of a modifying adjective The starch-splitting enzyme found in saliva is called *salivary* amylase, the one secreted by the pancreas (in pancreatic juice) is known as *pancreatic* amylase Although this system of naming is more descriptive, many enzymes have other names that had become well established before it was introduced and which still persist For instance, the salivary amylase is well known by the name of *ptyalin*, while almost everyone is familiar with the names of *pepsin* and *trypsin*, which are respectively the gastric and pancreatic proteases (protein-digesting enzymes in gastric and pancreatic juices).

The best known digestive enzymes, with their names and the reactions they bring about, are listed in the Summary of Digestion (table) above

It is interesting to note how, in the case of carbohydrates and proteins, enzymes secreted farther along in the alimentary canal pick up and carry on the digestive processes started by those higher up, also for the digestion of large molecules, such as starch and proteins, there are two enzymes or more so that any of the foodstuff that escapes digestion by the action of one enzyme will be subjected to digestion by others secreted lower down in the digestive tract This makes for very efficient utilization of carbohydrates and proteins in the food. Trypsin and erepsin, sometimes spoken of as if they were single enzymes, have been shown to consist of a group of enzymes, each with a highly specialized chemical task.

Fats are insoluble in water and their digestion is almost entirely dependent on the action of the enzyme steapsin in pancreatic juice *Bile*, which is discharged into the intestine along with the pancreatic juice, is important for good digestion of fats even though it contains no enzymes, it acts to emulsify fats in fine droplets, thus permitting more intimate contact with digestive juices, and to dissolve and assist in the absorption of the fatty acids formed by digestion so that they are removed from the intestinal contents and digestion goes to completion

Rennin is an enzyme contained in the gastric juice, which precipitates milk in solid form (curds), so that it does not leave the stomach as rapidly and digestion of its proteins by pepsin has a better chance to get started Heat-treated cow's milk and human milk form a finer, more eas-[illegible] abundant in [illegible] important [illegible] ic juice is sufficient alone to clot milk

Secretion of Digestive Fluids

A knowledge of the factors that *stimulate* and those that *inhibit* (slow down) the secretion of the digestive fluids is a help in securing favorable conditions for digestion. The secretion of *saliva* and *gastric juice* is largely controlled by ***nervous impulses***, but the flow of digestive fluids used in the *lower part* of the alimentary tract is relatively free from nervous control and is stimulated by "chemical messengers" carried in the blood and known as ***hormones***.

Small amounts of saliva and gastric juice are secreted all the time but their flow is stimulated when food is present to be acted on Factors that stimulate the flow of *saliva* are the mechanical stimuli of *chewing*, the taste, sight, smell, or even the thought of food. The latter type of stimuli cause what is known as ***"psychic secretion,"*** and the traditional "watering of the mouth" that occurs at odors or thoughts of appetizing food also causes the stomach to secrete more gastric juice in preparation for receiving food ***Appetite*** (a psychic factor) thus makes for good secretion of digestive juices and for better digestion, appetite is influenced in turn, either favorably or unfavorably, by one's state of mind, com-

panionship, and attractiveness of the table service and food, so that all these factors may have an influence on digestion Fear, anger, worry, strong emotions, and fatigue all exert a decided *inhibiting* effect, not only on the secretion of saliva (dryness of mouth in fright) but also on the flow of gastric juice, and have a strong effect in slowing down the muscular movements of the alimentary tract An apprehensive semi-invalid may thus actually induce "nervous indigestion" by an introspective state of mind and by the certainty that various foods will disagree with him On the other hand, a happy state of mind, zest for food, and thorough chewing are conducive to good digestion by starting things off with a good flow of saliva and gastric juice, and this in turn is likely to stimulate a more copious flow of the digestive fluids needed for intestinal digestion

Although the secretion of gastric juice and the motility of the stomach are sensitive to nervous and psychic influences as outlined above, by far the strongest stimulus to the secretion of *gastric juice* comes from the *presence of food in the stomach.* Some foods call forth a more copious secretion of gastric juice than others, meats and meat extractives (as in soups made from meat) are thought to have an especially stimulating effect on gastric secretion, the taking of some water with meals also promotes the flow of gastric juice Finally, the formation of a *hormone* called *gastrin* in the pyloric glands of the stomach, under influence of food present, has been demonstrated to stimulate the muscular activity of the stomach and the secretion of gastric juice After food has passed out of the stomach into the duodenum, a hormone is formed in the wall of the duodenum, which is carried through the blood to the stomach and acts to slow down the muscular and secretory activity of that organ

The chief stimulus to the secretion of the *pancreatic juice* and *bile* comes from a *hormone* called *secretin,* this hormone is formed in the wall of the duodenum by interaction with a substance or substances present in the acid "chyme" discharged from the stomach into the duodenum, carried by the blood to the various organs, it stimulates the flow of pancreatic juice, the secretion of bile, and probably also the secretion of intestinal juice So just as a hormone signaled back to the stomach to slow down as its work was nearly finished, secretin signals to the pancreas and liver to pour out their secretions when there is food ready for digestion in the duodenum, it also probably sends a signal ahead to the intestinal mucosa lower down to prepare its secretion for the oncoming task. Other hormones formed in the intestinal wall stimulate secretion of pancreatic and of intestinal juices, as well as the emptying of stored bile from the gallbladder

This system of digestive hormones, formed on contact of food material with the intestinal wall and used to send signals from one portion of the alimentary tract to another through the blood, affords an example of the ingenious manner in which the body organizes for the performance of a task. It is a considerable "factor of safety" in nutrition that nervous

factors do not disturb digestion below the stomach and that, even if there should be distress and poor gastric digestion, the later stages of digestion (in the intestine) are most likely to be carried out efficiently and thoroughly.

ABSORPTION

Absorption *is the process by which the products of digestion* pass through the lining of the intestine *into the blood* and lymph.[2] Simple sugars and amino acids are absorbed *directly* into the blood stream; the products of fat digestion pass chiefly into the *lymph*, which is collected through tiny lymph vessels and finally emptied into the blood (via the thoracic duct in the neck).

The exact mechanism by which absorption of products of fat digestion is accomplished has been thrown into doubt by recent research, but it is certain that the *bile* plays an essential role in enabling products such as glycerides and *fatty acids*, which are insoluble in water to pass through the membrane lining the intestine. Some think the action of the bile is mainly to form emulsions in which fatty acids or other non-soluble products are reduced to such minute particles that they can pass through the *intercellular spaces Others believe that these non-water-soluble products* enter into chemical combination with bile salts to form even more finely divided particles which are absorbed. Some fatty acids of smaller molecular size (short carbon chains) may pass directly into the blood but those with larger molecules (chains of 16 to 18 carbon atoms) pass preferably into the lymph. To what extent the cells of the intestinal mucosa recombine fatty acids and glycerol, during their transit through, to form fats and phospholipids for transport in the blood is now somewhat of a moot question, some may be recombined here and some by tissue cells elsewhere, as in the liver

When bile is prevented from emptying into the alimentary tract, as in obstructive jaundice, the clay-colored stools give evidence of the resultant poor fat absorption. Since bile also tends to keep down putrefactive *processes in the intestine, stools are foul smelling in its absence*

The *water-soluble* products of digestion, *sugars* and *amino acids* (as well as water-soluble vitamins and mineral salts, meat extractives, and water itself), pass readily through the intestinal membrane into the blood stream A good deal of water is absorbed from the large intestine.

The *absorption* of food material, however, *takes place almost en-* ... fact that the inner sur- ... reased by being thrown ... villi contains numerous small *blood vessels* and a *lymph space*, so that both the blood and lymph are brought very close to the intestinal membrane and the absorption of ... between the blood and ... not come directly in

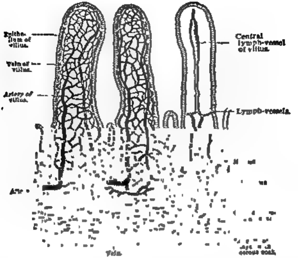

Figure 120 Diagram of cross-section of the human small intestine, showing projecting villi containing blood and lymph vessels for absorption of food Lower portion of the picture shows the layers of circular and longitudinal muscles useful in the movements of the intestine (Modified from F P Mall)

material from the intestinal contents is thus made easy The muscular contractions of the intestine also serve to bring its contents into close contact with its wall and to "milk" blood and lymph into and out of the villi. Because the breaking down of foodstuffs in digestion takes place gradually and the products of digestion are absorbed as they are formed, the body is not overwhelmed with a great surplus of newly absorbed food material at one time [3]

Anything which makes for *more intimate contact* of the intestinal contents with the lining membrane, or for *slower passage of food* through the small intestine, will *favor more complete absorption, incomplete absorption* may be the result of an irritated, highly *motile intestine* which hurries food through too rapidly, of the *formation of insoluble compounds* in the intestine, or, in the case of fat absorption, of *lack of bile* Absorption is usually very efficient and *complete,* most of the *foodstuffs are* 90-98 *per cent digested and absorbed* on a mixed diet and under normal conditions

CONDITIONS WHICH AFFECT DIGESTION

Under this heading we shall endeavor to summarize and discuss the practical applications of those *factors which make* either *for efficient functioning* and good health of the digestive organs, or for *digestive*

[3] This is one of the reasons why it is better to take carbohydrate in the form of starch, which is gradually digested, than as sugar, which is much more quickly absorbed, so is liable to flood the system with a surplus of sugar and may even result in the excretion of sugar in the urine when taken in large amounts

distress and functional disorders of the alimentary tract. As digestive complaints are very common, evidently securing the best conditions for the working of the digestive organs is none too easy. Proper regard for the digestive tract will enable one to forget its existence and, in addition, good digestion will promote general health and optimism As Brillat-Savarin commented,[4] *"Digestion is of all bodily functions the one which* most affects the moral state of the individual. The manner in which it is habitually performed makes us sad, gay, taciturn, talkative, morose, or melancholy, and we do not suspect the cause"

The chief factors which affect digestion may be grouped as follows:

(1) Nervous factors
(2) General nutritive factors
(3) Food factors.

Each of these factors acts either *by affecting the motor functions* of the digestive organs or *by exerting an influence on the flow of the digestive juices.* Different conditions will exert a favorable or unfavorable influence upon digestion, depending on whether they have a stimulating or inhibiting action.

Nervous Factors

Nervous factors are put first because they are probably of greater relative importance than the other groups. *Fear* or *worry, anger* or *irritation, nervous fatigue* or *stain, emotion* or *excitement* all exert a strongly *unfavorable* influence upon digestion (*especially in the stomach*), both by suppressing the flow of digestive fluids and by inhibiting the muscular activity of the alimentary tract The latter effect is well illustrated by Dr Cannon's[5] experiment of showing a puppy to a cat, whose digestive processes he was following by means of the x-ray. Digestion, which progressed normally at first, was inhibited for about *four hours* after the excitement incident to the sight of the dog. Such conditions as *concern about one's self,* monotony or *boredom, mental preoccupation* or *overstimulation* have similar unfavorable effects and are often associated with *lack of appetite,* which in itself constitutes an unfavorable factor.

The reverse conditions exert a *beneficial* influence on digestion through promoting good secretion of digestive fluids and proper muscular activity of the alimentary tract. Peace and *quiet,* cheerful but not *over-stimulating companionship, appetizing food,* and *attractive surroundings* all are factors that favor good digestion

General Nutritive Factors

It is a little difficult to show the direct influence of general nutritive factors upon digestion, but they need to be mentioned because it is well

[4] In "The Physiology of Taste," published in 1825
[5] W B Cannon, *formerly Professor of Physiology at Harvard Medical School*

recognized that the *"run-down" condition which results from indigestion,* with consequent poor utilization of food, eating small amounts, and eliminating many foods from the diet, constitutes a "vicious cycle" which results in still greater inability of the digestive organs to meet their tasks. The nervous individual who has developed fixed ideas that a number of foods are sure to disagree with him is almost certain to take a very *restricted or one-sided diet.* Such a diet is often poor in fruits, vegetables, whole grain cereals or milk, and hence low in certain vitamins and minerals. *Lack of vitamin B_1* is especially likely to be associated with lack of appetite and poor muscular tone of stomach and intestines, poor nutritive condition of the mucous membrane that lines the alimentary tract may be caused by *lack of vitamins A or C, or the B-complex vitamins.* The fact is that a person who is in *poor general nutritive condition,* whatever may be its cause, is extremely likely to show the effects of this condition in a *poorly functioning alimentary tract.*

Food Factors

This category includes the factors to which the lay mind attributes most of the ills of digestion, but they are less important than is usually supposed. The *healthy* stomach and intestines will *digest almost any ordinary food or combination of foods* without trouble. This does not mean, however, that they will handle any *quantity* of food or any *combination of foods difficult to digest* without rebelling, and habitual abuse in these respects will undoubtedly lead to digestive disorders. The reason many persons experience digestive distress when they eat foods or combinations of foods which they believe will give them trouble is that the *conviction of* and *apprehension of harm* to come is sufficient in itself to *cause the poor digestion* which follows. Moreover, the *distress* felt is practically always *due to poor gastric digestion* or failure of the stomach to empty promptly, and the offending foods are usually *well digested and absorbed later on in the intestines.*

A few people are unquestionably sensitive to certain foods and are made ill by them, but such *food sensitization or allergy*[a] is not very common and needs to be confirmed by the tests of a physician.

Probably it is safe to say that 90 per cent of the *digestive distress* which is *attributed to* the kind or combinations of *food eaten* is *due rather to conditions unfavorable for digestion*—such as mental or emotional states, to eating when overfatigued, to taking too large a quantity of food, or to eating at one meal too many foods which are difficult to digest.

Some types of food are digested more slowly than others, and hence require a more prolonged effort on the part of the digestive organs. In common parlance, such foods are spoken of as being "hard to digest," while other foods are said to be "easy to digest." In general, *liquid* foods,

[a] For fuller description of food sensitization or food allergy, see pages 453–454.

distress and functional disorders of the alimentary tract. As digestive complaints are very common, evidently securing the best conditions for the *working of the digestive organs is none too easy.* Proper regard for the digestive tract will enable one to forget its existence and, in addition, good digestion will promote general health and optimism As Brillat-Savarin commented,[4] "Digestion is of all bodily functions the one which most affects the moral state of the individual The manner in which it is habitually performed makes us sad, gay, taciturn, talkative, morose, or melancholy, and we do not suspect the cause."

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[illegible]

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same foods when *properly cooked.* These facts are a surprise to most people and are brought out here to emphasize the completeness of the later stages of digestion even under difficult conditions, and not with any idea of condoning poor cooking. Foods which are so poorly cooked as to be difficult to digest frequently cause *acute gastric distress* and, if eaten habitually, may result in chronic digestive disorders.

QUESTIONS

1. What is digestion? Why is it necessary? Describe the alimentary tract and show how it is especially adapted for carrying out the process of digestion

2 Describe the motor functions of the digestive tract, i e., how food is passed along through the alimentary tract from mouth to rectum What factors influence the emptying time of the stomach? What factors influence the length of time that food material stays in the intestines? How does the length of time that material stays in the intestines affect *the completeness of digestion and absorption?*

3 What are the end-products of digestion of proteins, starch, cane sugar, and fats? Name the principal digestive fluids that bring about the chemical break-down of these foodstuffs into their simplest components, tell where each of these digestive fluids is formed, and give the main *functions of each.*

4 Chemical changes involved in digestion are brought about or facilitated by the presence of enzymes in the digestive fluids What is an enzyme? What is meant by saying that enzymes are "specific" in their action? Can you name the different enzymes (and substances upon which they act) in gastric juice, pancreatic juice, and intestinal juice? What is the chemical nature of enzymes, and why is their activity destroyed by boiling? What are the optimum reactions and temperature for activity of the enzymes in saliva, in gastric juice, and in the digestive fluids in the intestine?

5. What are the chief factors that stimulate or inhibit the secretion of saliva and gastric juice? Explain the action of hormones in stimulating the flow of the digestive fluids that act upon food in the small intestine. What happens to food residues in the large intestine or colon? Why is it undesirable for food residues to remain for too long a time in the colon?

6 Describe how absorption of amino acids, simple sugars, and end-products of fat digestion takes place in the intestine. What substances taken in food can be absorbed without being chemically changed in digestion? Explain how bile helps in the digestion and absorption of fats What substances are found in the residues at the end of the digestive tract, the feces, and what factors alter the consistency and composition of the feces?

7. Discuss the effects of nervous factors, of the general nutritive condition of the individual, and of different types of food eaten, on the

finely divided or *soft* foods, and hard foods like dry toast or crackers, which must be well chewed, are those most easily handled by the digestive tract. *Fats* and *foods rich in fats* (especially mixtures of proteins with fats), foods which are introduced into the stomach in *large pieces* (and especially in chunks coated with fat), protein-rich foods which have been made *tough in texture* by overcooking, and foods in which the *cellulose fiber* has not been softened by long enough cooking, are those which are digested more slowly and place more of a tax on the alimentary tract. Many foods are intermediate between these two groups in the relative ease with which they are digested.

Naturally, it is the part of discretion to take only *small amounts* of the *easily digested foods* when one is *overfatigued*, after a *digestive upset* or other *illness* has weakened the digestive powers, or *when conditions* are otherwise *unfavorable for digestion*. This is the reason for the fluid and soft diets given to *invalids* and convalescents, when smaller amounts of food are usually given at shorter intervals. It is also the basis of diets for *infants* and *young children*, whose digestive powers are more limited than those of adults. Under all these conditions, it is a question of "tempering the wind to the shorn lamb," or of favoring the alimentary tract which is not equal to much strain by giving it a relatively easy digestive task.

Persons who spend much time *out-of-doors*, those who take *much exercise*, and those who are blessed with an *unusually healthy digestive tract* can often digest without apparent difficulty larger amounts of food and foods which are harder to digest than less robust individuals can handle, but even such persons cannot continually insult the stomach with impunity.

When the stomach gives such *distress signals* as *heaviness*, *gas*, *heartburn*, and *nausea*, it is well to allow it a little extra rest for recovery and not to repeat the indiscretions which caused the difficulty. *Most acute digestive distress comes from the stomach*, but spoiled foods and those which contain irritating substances will cause a *diarrhea*. chronic indigestion is likely to result in the formation of *gases* (through bacterial action in the intestine), which may cause acute pain through distention of the intestines. In the latter case the diet may be at fault, but it is more likely that the difficulty lies in the general condition of the individual, nervous or otherwise.

The *influence of cooking on digestion* is more through making the food *palatable* and *appetizing* than through any effect on the nutritive properties of the food. Most raw foods are well digested, but starchy foods and those that contain tough fiber need thorough cooking in order to rupture the starch granules and to soften the fiber, so that the digestive juices can penetrate them. There is seldom more than *5 per cent difference* between the extent to which *raw or poorly cooked foods* are ultimately digested and absorbed, and the degree of utilization of the

Metabolism and the Influence of Ductless Glands

METABOLISM is a word used so commonly that many people would like to have a more definite idea of what body processes are covered by it It is a *general* term used to designate all the ***chemical changes which occur in living matter in the course of its vital activities*** These changes are of two kinds—***constructive*** and ***destructive*** Constructive processes include all chemical changes by which the absorbed products of digestion are built into new ***tissues*** in growth or use for ***replacements*** to make good substances lost during life processes Destructive metabolism covers those processes by which either fuel foodstuffs, reserve tissue material, or even substances in cells, if necessary, are broken down into simple substances with the liberation of energy, which is needed for work and keeping the body warm The life of all the tissue cells is dependent on the many and varied chemical changes which are included under the general term of metabolism

Metabolism thus ***begins where digestion leaves off***. Food materials are broken down in digestion, it is true, but these processes take place

relative ease and comfort with which digestion is accomplished, upon the completeness of digestion. On basis of these facts, make a set of rules designed to promote good digestion and to avoid digestive distress

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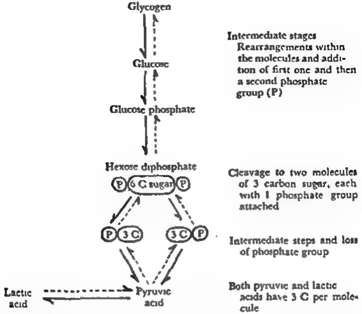


Figure 121 The first stages of carbohydrate metabolism, from glycogen (in liver and muscles) to pyruvic and lactic acids This is called the anaerobic phase because no extra oxygen is needed A relatively small amount of energy is set free, but this serves to supply the immediate energy needs for muscular contractions

urally depends somewhat upon whether the supply of carbohydrate (or of energy in other forms) in the diet has been *liberal* or *scanty*, but there is an *upper limit* beyond which no more glycogen can be stored

Excess carbohydrate intake, over and above the amount which can be converted into glycogen, *is stored in the form of fat* in the fatty tissues of the body This is why people inclined to be stout are urged to avoid taking an excess of sugar or starchy foods (as well as of fats) Something like one hundred times as many calories can be stored in the form of body fat as can be stored directly as carbohydrate (glycogen). In the case of food lack, the glycogen stores are practically exhausted in *one or two days*, after which the body draws largely on its reserves of fatty tissue for fuel The limited stores of glycogen in liver and muscles serve as an *overflow outlet* in carbohydrate metabolism and as a *short-interval fuel reserve*, while the main depots of extra fuel lie in the fat deposits in various parts of the body

But the ultimate fate of most of the carbohydrate in the day's food intake is not to be stored (unless one eats greatly in excess of body requirements) but to be used as *fuel to supply energy* for current body needs. The fact that glycogen in liver and muscles must be continuously reconverted to glucose to maintain the blood glucose at normal level shows that the tissues must be continually withdrawing glucose from

outside the tissues and serve merely to prepare substances for the use of the tissues Metabolism includes only such changes as occur in *living* matter.

The discussion in this chapter will be limited to the metabolism of the three chief foodstuffs—proteins, carbohydrates and fats. Intensive research in recent years has accumulated a mass of information about the intermediate compounds formed in the breaking down of the three foodstuffs, enzymes and coenzymes involved in bringing about these chemical changes, and ways in which intermediate products may be built interchangeably into one or another substance as needed by the body. Interesting and enlightening as this newer knowledge is, it involves complicated chemical processes that are beyond the scope of this book Moreover, in the maze of detail concerning intermediate processes in metabolism, the general, over-all picture of what happens to foodstuffs in the tissues may easily be lost. Hence, it seems best to present first a simplified version of the uses, breakdown, and end-products of the metabolism of carbohydrates, fats, and proteins, then to include some additional facts about intermediary metabolism in a separate section.

GENERAL STORY OF FATE OF THE FOODSTUFFS IN METABOLISM

Carbohydrates

The products of digestion of carbohydrates, chiefly *glucose* with smaller amounts of fructose and galactose, are absorbed from the intestine into the blood, which passes directly to the liver. After a meal rich in carbohydrates, there will be a great deal of glucose in the ***portal vein***, although the ***glucose content of the blood*** in circulation in the rest of the body is only slightly increased and soon returns to its remarkably *constant level*. It is evident that the liver has the ability to take up and alter fructose and galactose (since only glucose is found in the general circulation) and to remove excess glucose from the blood

The ***liver*** is the great ***regulator of the blood sugar*** and the main ***storage house for excess carbohydrate*** in the body. It takes the simple sugars brought to it from the intestine and condenses them to form a more complex and less soluble carbohydrate, a sort of "animal starch" called ***glycogen***. This name, meaning sugar former, is given to this compound because, whenever the body needs to call on its extra store of carbohydrate, the glycogen can be converted back into sugar (glucose) again and given up to the blood In this way the liver acts as a reservoir for excess carbohydrates to keep the body from being flooded with sugar just after meals and from running short of it at other times

To a lesser extent, the ***muscles*** share in this function, as they also can store small amounts of glycogen. Muscle glycogen is the material that can be readily drawn on for the energy needed for muscular work, liver glycogen is the reservoir from which the glucose of the blood can be replenished. The ***amount of glycogen in the liver*** and mu

The second stage constitutes the true *oxidative breakdown* of carbohydrate, from pyruvic acid to carbon dioxide and water, again through *many* intermediate products. Most of the so-called oxidation is accomplished by withdrawal of hydrogen atoms which are taken up by enzymes or coenzymes that act as hydrogen acceptors, it is only in the final steps that enzymes known as catalases cause transfer of electrons which enable the hydrogen to unite with oxygen to form water. Carbon dioxide is split off from various intermediary substances from time to time (by enzyme action) in the course of the process. For further details of this process see text and diagram of the "citric acid cycle" on pp. 382 to 384. The over-all equation given below will provide a general idea of what

$$\underset{\text{Pyruvic acid}}{\begin{matrix} CH_3 \\ | \\ C{=}O \\ | \\ COOH \end{matrix}} + \underset{\text{Water}}{3H_2O} \longrightarrow \underset{\text{Carbon dioxide}}{3CO_2} + \underset{\text{Hydrogen}}{10H}$$

has taken place. The complete oxidation of every molecule of pyruvic acid yields three CO_2 molecules (accounting for all three carbons in pyruvic acid) and 10 hydrogen atoms (6 from the water added in reactions), which go to form 5 molecules of water (H_2O) by combination with 5 oxygen atoms in the final stages of oxidation. Thus the end-products of the complete oxidation of carbohydrate are *carbon dioxide and water*.

Fats

Fats, not being soluble in water, are carried to the tissues as finely divided particles suspended in the blood. Some fatty acids and glycerol are also carried in the blood in combination as phospholipids and esters of cholesterol. After a meal rich in fats, the fluid part of the blood (plasma) is rendered turbid by the fat absorbed from the intestines, but this extra fat leaves the blood and passes into the tissues within a few hours.

Much of the fat is taken up by cells of the *liver*, which is as important in fat metabolism as it is in carbohydrate metabolism. The liver is responsible for working over fats brought to it into various related substances, which the body cells either need for their structure or can use for energy production more readily than the original fats. Thus some fat may be transformed into phospholipids, saturated fatty acids may be converted to unsaturated ones, and fats not characteristic of the animal may be built over into the arrangement that is needed for storage in the tissues. Phospholipids and cholesterol esters of fatty acids, which the liver also builds, are used in part to build into cell structure, concentrated at the outer part of the cells (cell wall) where they are believed to aid in the absorption of lipids from the blood into tissue cells. Although the liver is the main organ for thus "working over" fats, other

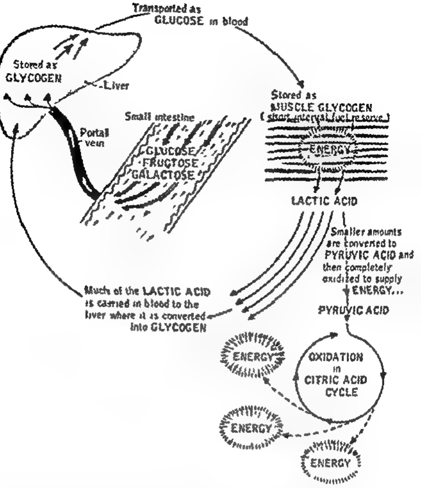


Figure 122 General scheme of carbohydrate metabolism, including the cycle of glycogen, glucose, lactic and pyruvic acids (anaerobic stage) and the final oxidative breakdown to carbon dioxide and water, setting free considerable energy.

the blood for their own uses The active tissues of the body, such as muscles and glands, get energy for their work from the breakdown of glucose (and to a lesser extent glycogen) brought to them by the blood This breakdown takes place in many intermediate stages, with a very gradual release of energy. The first phase, which itself consists of ten different steps, is known as the *anaerobic stage* because no oxygen is required for these processes, it consists of the conversion of glycogen to lactic acid by means of which only a small amount of energy is set free but enough to permit a muscle to operate temporarily when oxygen is not brought to it fast enough by the blood Only about one-fifth of the lactic acid formed is converted into the next product, pyruvic acid, and enters the cycle for complete oxidation, the rest is conserved and built back into glycogen in the liver and muscles (see Fig 122 above).

For a fatty acid like stearic acid, which has a chain of 18 carbon atoms, this series of reactions would have to be repeated eight times in order to produce 9 molecules of acetyl coenzyme A As two-carbon fragments are split off, they may lose coenzyme A, combine with an organic acid (oxalacetic) to form citric acid, and enter into the citric acid cycle (see p 382) for complete oxidation to carbon dioxide and water

These two-carbon fragments, acetyl coenzyme A, may also be used for building other substances in metabolism, including rebuilding of fatty acids if necessary. Since they are built up of two-carbon fragments, it is obvious why all naturally occurring fats have fatty acids with an even number of carbon atoms And since acetic acid or acetyl groups are formed in the process of metabolism of both carbohydrates and amino acids, it is easy to explain why fat can be built from either carbohydrate or protein when these are eaten in excess of the body needs for energy

Fat taken in excess of that used to supply energy for current body needs is usually *deposited in certain tissues* (adipose or fatty tissues) specialized to act as depositories for this substance The deposit of fat in the tissues always represents *fuel taken in excess of the energy needs of the body*, whether it is taken as fat or made from excess carbohydrate or protein Although adipose tissue was formerly thought to be rather inert, experiments with fatty acids "tagged" by containing an isotopic element indicate that there is a more active interchange of fatty acids between these tissues and the blood than was previously supposed Stored fat can, of course, be withdrawn from adipose tissue and oxidized to provide energy, whenever fuel foodstuffs are supplied in amounts insufficient for current body needs.

Proteins

The products of protein digestion, *amino acids*, are absorbed into the blood and carried in this form to the tissues, which take them up rapidly from the blood The amino acids that are *absorbed by the tissues* following a meal disappear within a few hours and there is evidence to show that the bulk of them have been used in one of three ways

(1) Recombined to make proteins needed for *building new tissues*, or individual amino acids are used for the *upkeep of tissue proteins* to replace some that are discarded from cells in their life processes

(2) Small amounts are put together in the proper proportions to build various hormones, enzymes, antibodies, etc, which are important for the body welfare and are known to be proteins in their nature At least one vitamin (niacin) can be made from an amino acid (tryptophan)

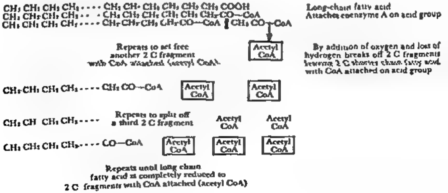
(3) Subjected to processes by which the nitrogen-containing part of the compound is split off, while the non-nitrogenous fragment that remains is either oxidized directly or converted into glucose, after which it is available for any of the uses outlined for that substance.

tissues can also perform the same chemical transformations. Experiments in which fatty acids "tagged" with heavy hydrogen were injected showed that desaturation and saturation of fatty acids go on constantly in the tissues

Most of the fat ingested is used as *body fuel* and is oxidized by the tissues with a resultant release of energy similar to that which takes place in the oxidation of glucose. Since fat is also made up of the elements carbon, hydrogen, and oxygen, the *end-products of its oxidation* are the same as formed by the complete oxidation of glucose, namely *carbon dioxide* and *water*, although the intermediate steps are very different and the amount of energy liberated is two and one-fourth times as great as would be produced by oxidizing an equal weight of glucose. Fat is thus a very *concentrated form of body fuel*

Before oxidation can take place fats must be broken down into glycerol and fatty acids, which follow different chemical paths of oxidation, *Glycerol* follows much the same route as glucose in metabolism, it is linked first with a phosphate group, is transformed to phospho-glyceric acid and later to pyruvic acid, through which compound it enters the regular cycle (see p 382) for complete oxidation to carbon dioxide and water The *fatty acids*, with their long chains of carbon atoms in the molecule, are disintegrated gradually into two-carbon fragments through the action of the important factor known as coenzyme A, breaking off two-carbon groups at each step of the process This process is started by the one acid group (COOH) at the end of the fatty acid molecule linking up with coenzyme A (by means of a sulfur, SH, group in the enzyme) The second carbon atom above the acid group is then transformed from a CH_2 to a CO group, at which point it is able to link up with a second molecule of coenzyme A, and the two-carbon fragment at the end of the chain is broken off, still with coenzyme A attached. This two-carbon fragment is called acetyl coenzyme A, pictured chemically as

$$\begin{array}{l} CH_3 \\ | \\ \text{CO—coenzyme A} \end{array}$$



Gradual oxidation of fatty acids, yielding 2-carbon fragments with coenzyme A attached (acetyl CoA).

amino acids which are able to take on an extra amino group (glutanic and aspartic acids), this extra amino group can later be passed on to another substance and so be used for forming amino acids from various intermediate compounds that arise in metabolic processes It is in this way that the body makes most of the amino acids described as non-essential, meaning that they do not have to be supplied by protein in the diet because they can be made in the body.

One other fact needs to be pointed out. The quota of amino acids that is deaminated and then oxidized of course yields energy, the quota that is built into tissue protein yields no energy to the body If the diet supplies carbohydrate and fat in too small amounts to meet the body's energy needs and more of the amino acids from protein have to be burned for fuel, the quota left for tissue building will be reduced, or may even be wiped out Hence, in growth, pregnancy, or recovery from wasting illness, when it is desirable to build up tissue protein in the body, sufficient other fuel foods must be available so that protein need not be burned as body fuel but can instead be stored in new tissues.

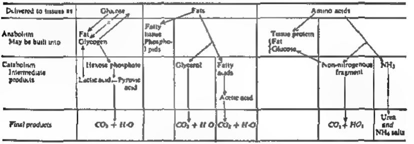


Figure 123 Condensed summary of the metabolism of the three fuel foodstuffs—carbohydrates, fats, and proteins

A simplified summary of metabolism of the three fuel foodstuffs is given above This diagram shows graphically that the final products of oxidation of all three are the same, *carbon dioxide* and *water*, with the exception of those substances formed from the nitrogen split off from the amino acids If the food supplies energy in excess of body needs, excess food material will follow the route indicated by arrows pointing to products of anabolism, i e, the excess will be chiefly built into glycogen or fat for storage If the food supplies energy inadequate to meet body needs, the insufficiency will be made up by destruction of some body materials, i e, by oxidizing first the stored glycogen, then fatty tissues, and finally tissue proteins in case of dire necessity

THE FINAL COMMON PATHWAY OF METABOLISM

The breakdown of carbohydrate, fat, and protein proceeds on more or less independent courses until a certain stage is reached, after which

The primary and unique function of amino acids is to enter into the composition of proteins for the *upkeep of tissue* proteins, including the important proteins of the blood, and to *build new protein* for cells in periods of *growth*. Formerly it was assumed that tissue proteins, once built, were fairly static and that the quantity of amino acids needed for their maintenance would be very small. We now know that tissue proteins, like many other body constituents, are in a state of dynamic equilibrium, exchanging some amino acids with those in the blood stream constantly. We also know that amino acids themselves are very labile compounds capable of being converted one into another and into substances other than tissue proteins. Schoenheimer[1] fed known amounts of *amino acids that contained isotopes of nitrogen* (N^{15}) *or hydrogen* (H^2), so that they could be identified later in the tissues, most of them were retained in the body and some were found incorporated into tissue proteins, some converted into other amino acids, while some had been used to make compounds other than protein.

Normally the body does not store protein and the excess of amino acids, provided by the diet but not needed for tissue upkeep, is carried by the blood to the liver where it undergoes "*deamination*," i e, splitting off of the nitrogen-containing amino group (NH_2). Most deamination occurs in the liver, but the kidneys also have enzymes that can perform this function, if needed. When an amino acid loses its NH_2 group, usually an organic acid is left that contains a keto group ($C{=}O$), these keto organic acids are *subject to oxidation*, either directly or after transformation into other compounds, depending upon the composition of the different amino acids. For instance, the simple amino acid alanine on deamination becomes pyruvic acid, which we have seen in carbohydrate metabolism can readily be oxidized to carbon dioxide and water. Some amino acids are said to be *glucogenic* because the deaminized fragment may be converted into glucose or some intermediate of carbohydrate metabolism. Other amino acids are said to be *ketogenic*, because on deamination they give rise to keto acids which can enter into fat metabolism. All of them are reducible to compounds that give entry into the "citric acid cycle" and thus provide for complete oxidation to carbon dioxide and water. Small amounts of them may be conserved and built over into other substances, as dictated by the body needs.

The fate of the *nitrogen-containing groups* split off from the amino acids presents a special metabolic problem. Most of this nitrogen (to the extent of 80 to 90 per cent of the nitrogen excreted) is transformed into *urea* in the liver and *excreted in the urine*, since the body is unable to store protein or other nitrogen-containing substances to any considerable extent (except in growth). A small fraction of the amino groups split off by deamination of amino acids may be conserved by union in two special

[1] Schoenheimer, R., The Dynamic State of Body Constituents, Harvard Univ. Press, 1942.

groups, or some compound that is a member of the ring) in order to be fully oxidized It might be likened to a turntable onto which the molecules of intermediate metabolism must get for the final disintegration to carbon dioxide and water

To permit the reader to visualize this metabolic turntable, the citric acid cycle is represented diagrammatically in Fig 124 A few intermediate substances are omitted, but all steps at which hydrogen or carbon dioxide are split off are included, also the compounds by which carbohydrate, glycerol, fatty acids, and amino acids enter the cycle The cycle moves only clock-wise, starting with citric acid and ending with oxalacetic acid, each revolution accomplishes the degradation of one molecule of the substance fed into it to carbon dioxide and water At the end, a molecule of oxalacetic acid is left, free to combine with another acetyl coenzyme A group to form citric acid and start the cycle over again.

One of the most interesting things about the citric acid cycle is that it enables us to understand how one foodstuff may apparently be converted into another Since below a certain point in their metabolism all three foodstuffs are reduced to identical intermediate compounds, a *common "pool" of two-carbon and three-carbon intermediates* is formed, which the body is able to put together in numerous ways to build substances that are more complex It does not build fat out of carbohydrate or protein as such, but from acetyl coA and pyruvic acid taken from this common "pool" to which all the foodstuffs have contributed Most enzyme actions are reversible (except those directly in the ring) and the reverse reactions possible are indicated in the diagram by dotted arrows This brings out the key position of the *acetyl coA*, which stands at the "crossroads of metabolism" (see diagram on p 384) Arrows pointing up from it (in the diagram) indicate the route by which it may give rise to glucose (or glycogen), to the left is an arrow showing that it may be coalesced to yield fatty acids or give rise to certain amino acids, an arrow leading right from pyruvic acid shows the route by which other amino acids and glycerol may be made, still other amino acids may arise from the ketoglutaric acid in the cycle So it does not matter which foodstuff has contributed the intermediates in the common pool, but from them any of the three (protein, fat, and carbohydrate) may be rebuilt, if desirable Many other normal body constituents (e g, cholesterol) may also be made from compounds in this common pool.

Each step in the citric acid cycle is catalyzed by specific *enzymes*, which are distributed in all the tissues The splitting off of CO_2 from pyruvic acid is accomplished by *carboxylase*, with the thiamine-containing coenzyme participating *Coenzyme A*, which contains the vitamin pantothenic acid, catalyzes the condensation of acetic and oxalacetic acids to give citric acid (as well as the earlier reduction of fatty acids to acetyl coA) Other carboxylases split off two more CO_2 molecules and *dehydrogenases* catalyze the splitting off of hydrogen at several stages,

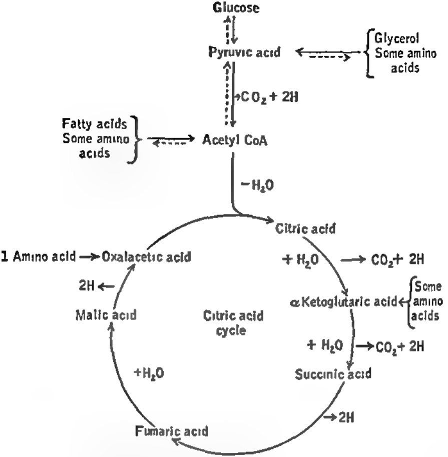


Figure 124 Diagram showing the common pathway for final oxidation of all three foodstuffs, the citric acid cycle The intermediate products of metabolism through which each enters the cycle are also indicated

they follow a common pathway in the final degradation to carbon dioxide and water. This common oxidative pathway is known as the citric acid cycle (from the initial compound in the ring), also as the tricarboxylic acid cycle (since it involves acids with three COOH groups), or the Krebs cycle (from the name of the man who first worked it out) It seems to be the regular pattern by which the body accomplishes the complete oxidation of any foodstuff, its full conversion to CO_2 and H_2O with maximum energy yield.

This pathway is referred to as a cycle because it is carried out through a chain or ring of compounds which are utilized and then regenerated, so that the process can start over again whenever another ...roup is available for ... to some compound ...cid, 2 carbon acetyl

to *regulate* and *coordinate* the *activities of the tissues*. When they are functioning normally, one is completely unaware of their existence and the metabolism of the body goes smoothly in all respects. When one or more of them become *overactive* or *underactive*, the normal *equilibrium* of the "endocrine system" is disturbed, leading to more or less grave *abnormalities of growth, sexual development, metabolism,* or *body functioning*.

The characteristic substances secreted by the different endocrine glands are known as ***hormones***,[2] and they have been called the ***"chemical messengers"*** of the body. Since they are very potent substances and are carried in the blood, small amounts may exert a decided effect on tissues throughout the whole body simultaneously. At least twenty ductless gland hormones have been isolated and studied, and most of them can now be synthesized in the laboratory. Many are proteins (with relatively small molecules) and two are derivatives of amino acids; others are derived from an important sterol (lipid) in blood and tissues, cholesterol.

Comprehensive discussion of the ductless glands, their numerous hormones and the many effects of these secretions on the body, is beyond the scope of this book. The discussion that follows is limited to the

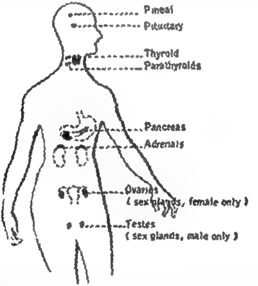


Figure 126. Diagram to indicate the various endocrine glands and their locations in the body. The tiny parathyroid glands are embedded in the thyroid, and the internal secretion of the pancreas (insulin) is made by specialized groups of cells (islands of Langerhans) scattered through the main tissue of the pancreas. The others exist and function as separate glands.

[2] We saw in the study of digestion (pp. 365–366) that hormones are also formed in the walls of the alimentary tract which serve to regulate motility of its organs and the flow of digestive juices.

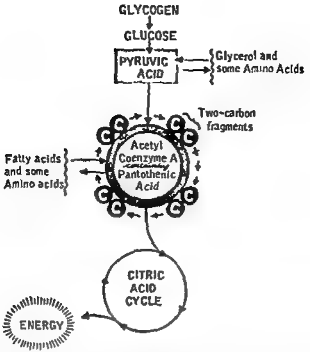


Figure 125 Drawing showing important, central position of acetyl coenzyme A in metabolism, as well as of the vitamin, pantothenic acid, which is a part of coenzyme A. The "pool" of two-carbon fragments (acetyl coenzyme A) is formed by metabolism of all three fuel foodstuffs and some of these molecules can be used to rebuild glucose or glycogen, glycerol and fatty acids (fats), and amino acids (for protein synthesis and upkeep). Probably most of them will be passed on into the citric acid cycle, by means of which they are oxidized to furnish energy for body needs. The strategic position of acetyl coenzyme A has been termed "the crossroads of metabolism."

with coenzymes that contain the vitamins riboflavin and niacinamide participating as hydrogen carriers. Thus deficiencies of these vitamins may interfere with the proper functioning of this important oxidative cycle. Mineral elements, such as iron, copper, and magnesium, also are contained in various oxidative enzymes and are necessary for their functioning.

INFLUENCE OF THE ENDOCRINE GLANDS ON METABOLISM

Perhaps the most important factor in directing and coordinating the metabolism of the different tissues is the influence of a number of small organs scattered throughout the body but grouped together under the term *ductless* or *endocrine* glands. They get this name because, while they consist of glandular tissue, they give up the characteristic substances which they manufacture *directly to the blood* circulating through them, rather than pouring their secretions out through a duct. Hence, they are said to have *internal secretions*.

The organs of internal secretion -

roxine (antithyroid drugs). In other cases, the surgical removal of all or most of the gland will be necessary in order to satisfactorily reduce the basal metabolic rate and secure relief of other symptoms.

Simple goiter is a nutritional disease, brought about by an insufficient supply of iodine, and was discussed in the chapter on Iodine (pp 177 to 181). The gland enlarges in an attempt to compensate by additional glandular tissue for the shortage of necessary material (iodine) for making its internal secretion (thyroxine). Basal metabolism may or may not be affected, depending on how successful the gland is in producing thyroxine under difficulties, but the symptoms of excessive thyroxine seen in so-called "toxic" goiters are conspicuously absent

A B

[illegible] before and after treatment for [illegible]

A B C

Figure 125 Patient before and after removal of thyroid gland because of exophthalmic goiter (overactive thyroid) *A* before operation—note thinness tense expression, protruding eyes, and enlarged thyroid *B*, two weeks after operation. *C*, one year after operation. (Crile, THE THYROID GLAND)

specific ways in which certain glands influence *metabolism and general nutrition*

Thyroid Gland

This gland consists of two lobes, located near the base of the neck, with a connecting "isthmus" across the trachea. Its chief function is to secrete an iodine-containing hormone, ***thyroxine***, which has a powerful effect in increasing the ***rate of oxidation processes*** in the tissues (basal metabolism). As little as a single milligram of thyroxine will raise basal metabolism 3 per cent above normal, apparently only about one-third *of a milligram needs to be released daily from storage in the thyroid into* the blood to keep basal metabolism at normal level. Thyroxine is a derivative of the amino acid tyrosine, with four iodine atoms in each molecule, as stored in the thyroid gland, it is part of a large protein molecule called thyroglobulin, but is slowly liberated into the blood as thyroxine, either free or combined with blood proteins. The thyroid gland also in some way influences growth, mentality, and deposition of fat in the body, as is evidenced by symptoms seen in the abnormal conditions when the gland is either under- or overactive (described below) A good many persons have slight under- or overactivity of the thyroid, but show the symptoms described to only a slight degree.

When the *thyroid is markedly underactive and secretes too little* thyroxine, this is evidenced by *low basal metabolism*, sluggish mentality, and overgrowth of fatty tissues A child who is born with the thyroid gland lacking or underdeveloped is called a ***cretin*** and is either a pot-bellied dwarf or a pudgy, stunted child with limited intelligence. Such a child may usually be made to grow and develop fairly normally by administration of thyroxine. Underactivity of the thyroid in later life results in a condition known as ***myxedema***, since it is characterized by puffiness of the hands and face and thick, dry skin, there is also low basal metabolism, blunting of mental activity, sluggishness of body processes, and a tendency to put on weight, especially when the disorder occurs in *women at the time of the menopause Basal metabolism may* be markedly increased by giving thyroxine, which also induces improvement in the other symptoms

Hyperthyroidism, or overactivity of the thyroid with secretion of thyroxine in too large amounts, is evidenced by abnormally *high rate of basal metabolism*, emaciation, rapid heartbeat, nervousness, and frequently by protruding eyes. The overactive gland usually becomes more or less enlarged, and such a condition is known as "toxic" or exophthalmic goiter (the latter name because of the eye involvement). The energy consumption may be speeded up to two or three times the normal rate, causing loss of weight in spite of increased consumption of food. In less severe cases, the overactive gland may be quieted by rest or by giving drugs that interfere with and partially suppress the formation of thy-

roxine (antithyroid drugs). In other cases, the surgical removal of all or most of the gland will be necessary in order to satisfactorily reduce the basal metabolic rate and secure relief of other symptoms

Simple goiter is a nutritional disease, brought about by an insufficient supply of iodine, and was discussed in the chapter on Iodine (pp. 177 to 181) The gland enlarges in an attempt to compensate by additional glandular tissue for the shortage of necessary material (iodine) for making its internal secretion (thyroxine). Basal metabolism may or may not be affected, depending on how successful the gland is in producing thyroxine under difficulties, but the symptoms of excessive thyroxine seen in so-called "toxic" goiters are conspicuously absent.

A B

[illegible]

A B C

Figure 128 Patient before and after removal of thyroid gland because of exophthalmic goiter (overactive thyroid) *A*, before operation—note thinness, tense expression, protruding eyes, and enlarged thyroid *B*, two weeks after operation *C*, one year after operation (Crile, THE THYROID GLAND)

Adrenal Glands

The adrenal glands are two small glands located just above the kidneys. These glands secrete hormones into the blood which, among their other effects, have a quick but transient effect upon energy metabolism The *hormone secreted by the inner portion of these glands is known as* ***adrenaline*** or ***epinephrine***.[3] Ordinarily this potent hormone is released in very small amounts but under the influence of fear, anger, or other emotional states extra quantities of adrenaline are poured into the blood and gear the whole body for the muscular action that would accompany such emotions under primitive conditions (flight in case of fear, fight in case of anger). Heartbeat is quickened, blood pressure rises, extra sugar is released from the liver into the blood, blood is shifted from the internal organs to the muscles, and oxidations in the tissues are temporarily speeded up (for discussion of the influence on basal metabolism, see page 46).

The outer portion (cortex) of these glands acts like a separate gland and secretes at least three hormones, all of which are derivatives of cholesterol The secretions of the adrenal cortex are essential for life[4] One of these hormones exerts a controlling effect on carbohydrate metabolism (increases level of blood sugar), while another has a specific action upon the metabolism of the mineral elements, ***sodium*** and ***potassium***. *When this second hormone is lacking, there is increased excretion* of sodium in the urine and subnormal sodium content of the blood, the concentration of potassium in the blood is abnormally high. A third hormone from the adrenal cortex is the much talked of ***cortisone***, which in some way acts to slow the growth of connective-tissue cells and the formation of complex polysaccharides in these tissues, injections of this hormone give relief from pain and crippling effects in some cases of rheumatoid arthritis, and have been helpful also in rheumatic fever and bursitis Similar effects have also been obtained by administering a pituitary hormone (ACTH) that stimulates activity of the adrenal cortex in secreting its hormones

Parathyroid Glands

The parathyroid glands also secrete a hormone that has a decided influence on mineral metabolism They are minute structures, embedded in or closely associated with the thyroid gland, usually one pair to each lobe of the gland When the parathyroids are completely removed, the amount of *the element calcium circulating in the blood is so much re-*

duced that ***tetany*** (convulsive muscular tremors) sets in, and death results When they are underactive, blood calcium is below normal, in rare cases where they are overactive, blood calcium is at a high level and calcium is drained away in the urine to an extent that the bones suffer excessive loss of calcium In ***regulating the calcium content of the blood,*** parathyroid hormone is intimately concerned in the metabolism of calcium

Pancreas

In the pancreas there also exist small groups of special cells (called islands of Langerhans), scattered throughout the ordinary gland tissue, which manufacture a very important hormone The pancreas thus has both an *external* secretion, pancreatic juice, which it pours into the digestive tract through a duct, and an *internal* secretion, which it gives up to the blood The hormone secreted by the pancreas is called ***insulin.*** It has been crystallized and its chemical structure established It is a protein with small molecules that consist of only a few different amino acids

Insulin is necessary to enable the tissues to *oxidize glucose,* and it also promotes the storage of glucose as *glycogen* in the liver and muscles When the metabolism of carbohydrate is thus limited by lack of insulin, there is increased burning of fats with production of the lower intermediates of fat metabolism (such as acetoacetic acid) in amounts greater than can be oxidized by the tissues Protein metabolism is also deranged, with more amino acids converted to glucose than normal The result of this condition is that glucose accumulates in the blood and is excreted in the urine, while if the condition is severe acetoacetic acid and acetone also accumulate in the blood (acidosis) and are found in the urine This abnormal metabolic condition is known as ***diabetes***

In mild diabetes the disease can often be held in check merely by ***limiting the quantity of carbohydrate food eaten.*** With only small amounts of sugars and starches to be broken down into glucose in the digestive tract, the amount of this substance carried to the tissues will not exceed what they can store or oxidize with the limited amount of insulin available If more insulin is required to keep the patient in good nutritive condition, it must be injected subcutaneously, since (as a protein) it will be destroyed by digestion when taken by mouth Injection of suitable amounts of insulin will cause the abnormally high blood sugar in diabetics to fall rapidly and return to normal Slowly absorbed preparations of insulin are available, which need to be taken only once or twice a day Some new drugs are now on the market which can be taken by mouth and have the effect of lowering blood sugar and, when combined with dietary control, are helpful in milder cases of diabetes However, since the hormone insulin is essential for normal carbohydrate metabolism (and indirectly for that of fat and protein), nothing can quite take its

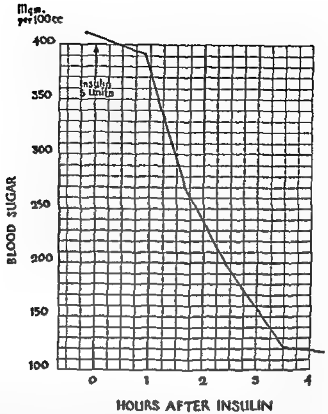


Figure 129. Effect of injecting five units of insulin in a patient with severe diabetes and sugar content of the blood about four times the normal amount. Note rapid response with fall of blood sugar almost to normal. (Courtesy of Dr. Alexander Marble, of Boston, Mass.)

place for enabling the patient to take a more adequate diet and thus be maintained in better health.

Pituitary Gland

The pituitary gland, which lies in a groove at the base of the brain, also secretes very powerful substances into the blood. It is composed of two distinct parts, called the anterior and posterior lobes, each of which secretes a number of different hormones.

The anterior lobe of the pituitary is often referred to as the "master gland" among the endocrine glands of the body. This is because it ... *ductless* ... l concern ... their influence on other glands. The physiological effects of anterior pituitary hormones include:

(1) Stimulation of the thyroid, parathyroid, adrenal (cortex), and sex glands
(2) Action on carbohydrate metabolism which is the opposite of that of the pancreatic hormone, insulin

Thus the anterior pituitary has a direct influence on carbohydrate metabolism through a hormone that is said to be "diabetogenic," in that it tends to flood the body with sugar by releasing it from liver glycogen, while insulin promotes the storage and utilization of carbohydrates. It also has an indirect influence on basal energy production, and on the metabolism of carbohydrates, fats, and mineral elements, through the effects of its hormones in stimulating other ductless glands.

QUESTIONS

1. Define metabolism. Why is digestion not included in metabolism? What is meant by metabolism of the fuel foodstuffs? by mineral metabolism? What happens when the intake of fuel foodstuffs is just about sufficient for the energy needs of the body? when it is in excess of body needs? and when it is inadequate for body needs?

2. Describe the metabolism of carbohydrate, covering the following points: the form in which it is absorbed from the intestine into the blood, the form in which it is carried in the blood to the tissues, the role of the liver in carbohydrate metabolism, the fate of glucose in the tissues (both that needed to supply energy and that in excess of immediate needs), the final products of carbohydrate metabolism.

3. Describe the metabolism of fats, covering the same general points listed above for carbohydrate metabolism. Describe the chemical changes that amino acids undergo in the tissues, including the fate of both the nitrogenous and non-nitrogenous parts of the molecule. What are the chief end-products of the metabolism of the three fuel foodstuffs?

4. What common pathway do all three foodstuffs follow in the final stages of oxidation to carbon dioxide and water? Why is this route called a "cycle," why the citric or carboxylic acid cycle? Why is acetyl coenzyme A in such an important position in the cycle? What are the advantages of having a "common pool" of lower metabolites from all three foodstuffs?

5. What are the endocrine or ductless glands, and what is a hormone? What is the hormone secreted by the thyroid gland, and what unique constituent does it contain? How does the thyroid hormone influence metabolism, and what are the effects of oversecretion and undersecretion of this hormone?

6. What gland secretes insulin and what is its role in carbohydrate metabolism? In what disease is insulin formed in insufficient amounts? What symptoms are indicative of insulin lack, and in what ways may the disease be treated?

7 For each of the following ductless glands, tell what influence their hormone or hormones have on metabolism: adrenal cortex, parathyroids, anterior lobe of the pituitary gland.

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Excretion and the Factors Affecting It

What the Waste Products Are

In the discussion of metabolism of the fuel foodstuffs, the fact was emphasized that all three of them yield the same end-products of oxidation, namely *carbon dioxide* and *water*. These products are formed by the burning of any fuel, such as wood, coal, or gasoline. Although the body has use for a certain amount of carbon dioxide and water, the excess of them which is constantly being formed must be excreted.

In addition to the gases formed when fuel burns, there are ashes left behind. Certain *nitrogen-containing substances* and several kinds of *inorganic salts*, chiefly end-products of the metabolism of proteins, may be thought of as the ashes of metabolism, since they are of no use to the body, are difficult to get rid of, and may cause trouble if they are not

excreted[1] We may divide the waste products, which *it is* necessary to keep from accumulating in the body, into the following groups

(1) Carbon dioxide
(2) Water
(3) Nitrogenous substances
(4) Mineral salts

Organs of Excretion

The organs of excretion are likewise four in number—the lungs, the skin, the kidneys, and the intestine The listing below summarizes briefly the waste products handled by the different organs of excretion, while the functioning of each of these organs is described somewhat more in detail in the paragraphs which follow.

Lungs	excrete carbon dioxide and water
Skin	excretes mainly water
Kidneys	excrete water, salts, and nitrogenous substances.
Intestine	excretes mineral salts, waste products in bile, the food residues, and some water

Excretion through the Lungs

The lungs are the only channel for *getting rid of the surplus carbon dioxide* that is continually being formed by the oxidation of fuel foods in the tissues The function of the lungs is doubly important, since they are also solely responsible for *recharging the blood with oxygen*, which is essential for oxidative processes in the tissues without which life cannot be maintained.

Excess *carbon dioxide* passes into the blood from the tissues and is held in loose chemical and physical combinations in the circulating blood When the blood reaches the lungs, it is brought into contact in the fine capillaries with air in the innumerable small air sacs of the lungs —that is, there is between the blood and air only a double membrane consisting of the very thin walls of the capillary and of the air sac, and this partition is of a nature to permit the free exchange of gases Accordingly, *in passing through the lungs the blood loses about one-sixth of its carbon dioxide content* in gaseous form to the carbon dioxide-poor air in the lungs, *and takes up from inspired air gaseous oxygen, which is* carried to the tissues in loose chemical combination with the blood pig-

to synthesize amino acids in the body is a common metabolic reaction Just as iron is conserved and used over again, so those fractions of CO_2 and NH_2 that are reserved for reuse would not be considered true "waste" products

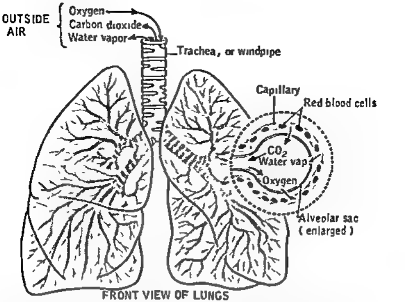

Figure 130 The lungs are alternately expanded and partially collapsed (by action of the chest muscles and diaphragm) to inhale and exhale air In the tissues toward the ends of air passages are tiny air sacs (see enlarged diagram of alveolar sac in above drawing), where exchange of gases between the blood and inspired air takes place

ment, *hemoglobin* Fresh air contains only 0 03 to 0 04 per cent of carbon dioxide[2] and about 20 per cent of oxygen The process of *respiration* in animals consists essentially of taking up 4–5 per cent of oxygen from the inspired air and giving off 3–4 per cent of carbon dioxide to the expired air Incidentally, the inspired air becomes saturated with *water vapor* while in the lungs, which accounts for the considerable and constant loss of water through the lungs

Under *factors which influence respiration* may be listed anything which affects the depth or frequency of the breathing The chest muscles and diaphragm form a bellows by means of which air is alternately sucked into and forced out of the lungs, these organs themselves being merely passive. *Frequency* of respiration is controlled by the *respiratory center* in the brain, this center in turn being chiefly affected by the *carbon dioxide content of the blood.*[3] Thus after exercise, during which the

[2] Although the carbon dioxide content of the air is increased in cities and in crowded rooms, it seldom reaches a point where it contaminates the air to any serious extent It is kept from accumulating in the atmosphere as a whole, because plants take up from the air the carbon dioxide which animals give off The very real discomfort felt in a

production of carbon dioxide is more rapid, stimulation of the respiratory center causes an increased rate of breathing, with the result that the excess of carbon dioxide is removed from the body through the increased ventilation of the lungs. *Depth* of respiration is a good deal a matter of habit and posture. In ordinary shallow breathing only about 1/6 to 1/5 of the air contained in the lungs is involved. This means that, although the whole volume of air is probably fairly efficiently renewed at least twice every minute,[4] the upper portion of the lungs usually gets little exercise. The need of taking deep breaths occasionally will be apparent. Efficient respiration is an important factor in good health, everyday factors which affect respiration are *habit, posture*, and *exercise*.

Excretion through the Skin

Through the activity of the sweat glands in the skin, *water* is lost from the body in the perspiration. Although the perspiration also contains small amounts of the nitrogenous waste product, urea, and of mineral salts (also traces of water-soluble vitamins), the value of the skin as an excretory organ is chiefly confined to its influence in removing water. The average person loses about a quart of water daily through the combined channels of the skin (perspiration) and lungs (respiration), five or six ounces more in the stool, and the remainder through the kidneys. The relative amount excreted by the skin will be largely determined by the amount of perspiration *needed* to take care of ridding the body of excess heat, i.e., for the *temperature regulation* of the body. In *hot weather* or after extra heat production through *exercise*, there is greatly increased perspiration and evaporation of water from the body surface in effecting the loss of heat necessary to temperature regulation. On a cold or humid day, or when there is little physical exertion, much less water is excreted through the skin and more by the kidneys. Hence the *temperature* and *humidity* of the surrounding air, along with *exercise*, are the chief factors that affect the excretion of water by means of the skin.

Excretion by the Kidneys

The kidneys are two glandular organs situated in the back of the abdominal cavity on either side of the spinal column at about the level of the twelfth rib. They are directly connected, by means of a large artery and vein respectively, with the main arterial and venous trunks of the body, so that they are *perfused by an exceptionally large amount of blood*. They secrete the *urine*, a fluid which is secreted continuously (although more rapidly under certain stimuli). The urine is collected in the urinary bladder, and is discharged at intervals through a duct leading to the exterior of the body (see Fig. 131, p. 398).

Of the waste products excreted in the urine, *water* is by far the largest in quantity (urine consists of about 96 per cent water). Also

[4] The usual rate of breathing is fourteen to eighteen times per minute.

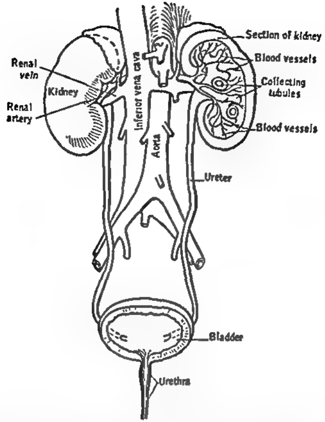

Figure 181 Diagram of the kidneys, their direct connection with main arteries and veins, and the outlet for their secretion (urine) through the ureters to the bladder

a greater proportion of the water loss from the body is effected by the kidneys than by any other route, although it is notable that some water leaves the body through each of the excretory channels. When an unusual amount of water is lost through the skin in hot weather (or through the alimentary tract in such abnormal conditions as vomiting and diarrhea), the amount excreted by the kidneys is correspondingly less.

The next most important constituents of urine are the *nitrogenous end-products of protein metabolism* (see page 380). One of these alone, *urea*, makes up about half of the total solids of the urine and constitutes the form in which 80–90 per cent of the nitrogen from metabolized proteins is excreted Smaller amounts of *uric acid*, *creatinine* and *ammonium salts* are the other nitrogen-containing constituents of urine These nitrogenous waste products can be eliminated from the body *only* through the activity of the kidneys Although they are not toxic in the amounts ordinarily present in the blood, if the kidneys fail to excrete these substances efficiently and they accumulate in the blood to a certain level, toxic symptoms set in. This is the cause of the uremic poisoning which oc-

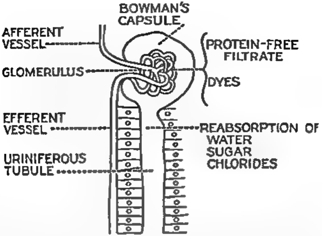

Figure 132 Diagram to show method of urine secretion—formation of protein-free filtrate from blood through glomeruli, and reabsorption of certain constituents by cells of urinary tubules These collecting tubules are coiled and much longer than shown in the diagram (After Hawk and Bergeim, Physiological Chemistry, The Blakiston Co)

curs in the later stages of kidney disease (Bright's disease or nephritis)

Finally, several kinds of ***mineral salts*** are excreted by the kidneys, which share with the intestine the duty of ridding the body of an excess of these substances, although the ***bulk of the salts leaves the body in the urine*** *Sodium chloride*, common salt, is excreted solely in the urine, and its source is the salt eaten in the food *Phosphates* and *sulfates* come chiefly from the metabolism of the proteins which contain phosphorus and sulfur. Other salts are largely those ingested in the food When the kidneys fail to function well, salts may accumulate in the blood and tissues, holding back sufficient water to dilute them to their normal concentration in the tissues (see page 128) and thus causing the bloating or edema which often accompanies diseases of the kidneys

Factors Which Affect Excretion through the Kidneys The factors which affect excretion through the kidneys may be listed as follows.

(1) Amount of blood supply
(2) Action of diuretics
(3) Amount of water taken
(4) Health of kidneys

The extent to which the ***amount of blood*** sent through the kidney influences the secretion of urine is often unappreciated, although the importance of this factor is obvious when it is pointed out Naturally a larger volume of urine is excreted when a great deal of blood is shunted through the renal circulation than when the kidneys are less

richly supplied with blood. This accounts for the *increased flow of urine* under conditions of *nervous stimulation,* and for a slightly decreased secretion when large amounts of blood are diverted to other parts of the body. *Diuretics* are substances which exert a stimulating effect on the kidneys. *Coffee* and *tea* both stimulate the kidneys to increase secretion of urine and are the only diuretics in common use except *water,* which is an excellent diuretic.

It is very generally recognized that *drinking large amounts of water* results in the secretion of a much increased volume of urine. This urine is very light in color and more dilute than the usual in its content of dissolved solids. In other words, the amount of pigment and waste products excreted remains about the same, so that the extra water merely renders the urine more dilute. The common conception that drinking a great deal of water "flushes the system" of many waste products which would otherwise not be excreted is a rather exaggerated notion, since ordinarily the kidneys and other organs of excretion rid the body of waste material efficiently day by day and do not allow "toxic substances" to accumulate even when the water intake is less than the optimum. However, there are many reasons why a liberal consumption of water is a good hygienic measure, as water is needed in the body for many purposes (see page 135). In addition, conditions are probably more favorable for the kidney to do its work when plenty of water is excreted along with the waste products than when it has to secrete a very concentrated urine. Thus, drinking plenty of water (6–8 glasses per day) is to be encouraged, but taking an excessive amount of it confers no special benefit and merely places an added burden on the kidneys.

This brings us to the fourth, and probably the most important, factor in urinary excretion, namely the maintenance of *healthy kidney tissues.* We know that there is a large "factor of safety" in this respect. The body is equipped with two of these organs, although it has been estimated that half of one kidney is sufficient to meet the body needs for excretion through the urine, provided it is in healthy condition. *It seems reasonable* to believe (although it is not absolutely established by scientific experiments) that the kidneys, like any other organs, are benefited by conditions which make for an easier performance of their duties, and are apt to give out in time if subjected to undue *strain* or constant *irritation.* Alcohol and pepper are both kidney irritants. It has been maintained that the necessity of excreting large amounts of nitrogenous waste products and of mineral salts, such as follows the habitual eating of excessive quantities of protein-rich foods and salt, constitutes an undue strain on the kidneys which may lead to their breakdown in later life. It is certainly true that conditions such as high blood pressure and heart disease will eventually result in circulatory damage to the kidneys and such diseases are, therefore, almost invariably associated in their later stages with a failure of the kidneys to function pr

to the kidneys are *bacterial invasion* of the kidneys themselves, bacterial *toxins* produced by a general or local infection (scarlet fever, diphtheria, tonsillitis, etc), and *poisoning* with certain substances such as compounds of the heavy metals (e g, bichloride of mercury)

Whatever the cause, ***damage to the kidney tissues*** results in a less efficient functioning of these organs which may show itself in one of several ways according to the severity of the kidney injury—namely, *inability to produce a more dilute or more concentrated urine*, when fluids are forced or withdrawn, a *diminished excretion of salts* and *nitrogenous substances*, often accompanied by increased secretion of water, a *diminished excretion* both of *water* and of the waste products in the urine, the appearance in the urine of *protein*, an abnormal constituent whose presence is usually indicative of nephritis

When the kidneys are known to be *weakened or diseased*, the natural procedure is to lighten their load by ***limiting the intake of those substances*** which give rise in metabolism to end-products that have to be ***excreted by the kidneys.*** Hence, the amount of *protein* and *salt* in the diet of nephritic persons is usually limited somewhat (or in severe nephritis may be kept down to the minimum needed for body maintenance), and in addition it is sometimes necessary to limit the *water* intake in nephritis

Excretion through the Intestine

The material expelled through the anus, the opening at the lower end of the alimentary canal, is called feces, and the feces consist of

(1) Small amounts of true *excretory material*,
(2) *Indigestible* and *undigested food residues*,
(3) Residues from *digestive secretions*, *mucus*, and *cell debris* from the lining of the alimentary tract,
(4) *Bacteria* and the products of their action,
(5) *Water.*

It will be apparent that the ***bulk of the feces*** is made up of ***food and digestive residues***, and that their expulsion is necessary more for the purpose of clearing the digestive tract to take care of new food material than for getting rid of the waste products of metabolism Nevertheless, some *mineral salts* (notably salts of calcium and phosphorus) are excreted through the intestinal wall into the lower digestive tract and certain *waste products are found in the bile*, which is secreted by the liver and emptied into the duodenum These substances together constitute the true excretory material contained in the feces The *pigment* which gives the feces their brown color may also be included in this class, since it is formed from the bile pigment, which in turn comes from the blood pigment.

Feces of ordinary semisolid consistency contain 60–70 per cent

of *water*, but the water content will be higher if the fecal material is hurried through the alimentary tract, and lower when its excretion is long delayed. About one-tenth or more of the feces consists of *bacteria* (both living and dead), and the number excreted per day has been estimated as varying between 50 and 500 billions. The presence of bacteria in the intestinal contents is entirely normal and some of them may even be beneficial in that they synthesize B-complex vitamins However, too large a number of bacteria or the predominance of the more harmful types is to be deplored from the standpoint of intestinal hygiene. The predominance of the fermentative types of bacteria (those that act on carbohydrates) over the putrefactive types (those that break down protein material) is recommended as advantageous. The number and strains of bacteria which flourish in the intestine are chiefly determined by the *character of the diet* and the *condition of the individual.*

FACTORS WHICH AFFECT EXCRETION THROUGH THE INTESTINES These are summarized in the following outline.

FECAL EXCRETION INFLUENCED BY

- **Tone of intestinal muscles—affected by**
  - General condition
  - Diet
  - Posture
  - Exercise
- **Sensitiveness to nervous stimuli leading to defecation—affected by**
  - Individual nervous sensitiveness
  - Habit
  - Psychic influences
- **Nature of intestinal contents—affected by**
  - Bulk and consistency
    - Depends on amounts of cellulose, water, and gas
  - Lubrication
    - Depends on amount of water and undigested fat
  - Presence of substances which stimulate peristalsis
    - Organic acids, especially in fruits and sour milk
    - Irritating substances such as hard materials, undigested food or spoiled food
    - Laxatives, enemas, etc

It seems worth while to take up the subject of excretion through the intestines in considerable detail, since *constipation*, or inefficient excretion through the intestine, is one of the prevalent difficulties of modern people This is due largely to faulty habits of living and to eating highly refined foods from which most of the roughage has been removed, but it should be noted from the many factors listed above that the problem of constipation is far from a simple one *It is often necessary to right* several faulty conditions in order to secure satisfactory elimination

One important factor is the *tone of the intestinal muscles.* If the intestinal mucosa is very sensitive or the person is in a hypersensitive nervous state, the colon may be stimulated to *too great muscular activity,* may contract excessively and shut down the cavity so as to prevent free passage of fecal material On the other hand, when an individual is poorly nourished or in a "run-down" condition from any cause, the in-

testinal muscles are likely to be *flabby* and in *poor tone*, so that peristaltic contractions of the colon take place infrequently and with insufficient force Such a condition of poor muscle tone of the intestine is often the primary factor responsible for constipation

Sensitiveness to the nervous stimuli which initiate the process of defecation[5] is important *Differences in nervous sensitiveness* are probably responsible for the wide differences in individuals as to the frequency with which they must empty the bowel in order to secure comfort By *ignoring* the nervous stimuli, to which the presence of feces in the rectum gives rise, the desire and ability to defecate pass, and repeating this offense results in blunting the sensitiveness to these stimuli This explains the important part which *habit* plays in securing normal bowel movements. The normal stimulus to defecate comes after meals, especially after breakfast, and if taken advantage of at such times rather than neglected, the colon can be trained to evacuate itself at regular intervals. *Psychic influences*, such as hurry, fear of inability to defecate and overanxiety to have a movement daily, have the effect of inhibiting these stimuli and preventing the normal reflex which causes the colon to contract and expel its contents In training children to proper habits of evacuation, mothers often find that over-attention to and nagging about this function produce the opposite effect from the one desired Neurotic persons often show a high degree of constipation due to psychic influences

Under the head of the *nature of the intestinal contents*, we have grouped a number of those factors which are most apt to receive attention in correcting constipation When the intestinal contents are of the proper *bulk* and *consistency*, they are not only easier to move along but more likely to stimulate the intestine to active muscular movements The contents of the colon should be semisolid, nonirritating, relatively free of undigested food residues, and of sufficient bulk, in order to secure good peristaltic movements and easy propulsion of the fecal mass The diet is largely responsible for securing these conditions Enough *high-residue foods*, that is, those that contain considerable cellulose, must be taken to give bulk to the fecal material

The presence either of plenty of *water* or of slight *fermentation*, which tends to break up the fecal mass by the formation of gas bubbles, favors a *soft, bulky* intestinal content Hard, dry feces are difficult to push along and fail to stimulate peristalsis, especially when small in bulk *Lubrication* between the fecal material and the intestinal wall is promoted by the presence of extra liquid or of undigested *fat* *Water* is the best lubricant, since under ordinary circumstances food fats are almost completely digested and absorbed before the colon is reached

The presence of *harsh, irritating substances*, of undigested food

[5] Defecation is the act of expelling the feces through the anus, thereby emptying the rectum and lower part of the colon of their contents

residues, of toxic or chemically irritating substances in the intestine *sets up increased peristalsis,* which tends to rid the alimentary tract of the irritating material. This may be taken advantage of when there is need to stimulate a *muscularly inactive colon* (*e.g.*, *adding bran* to the food), but if overdone it will lead to unfortunate results such as *diarrhea,* inflammed conditions like *colitis,* and the spasmodic contractions of the intestine seen in *spastic constipation.* The continual taking of *cathartics also acts as an irritant to the intestine* and produces bad results in the same way. *Saline* cathartics act by drawing water into the intestine, for the presence of liquid in the colon serves to stimulate peristaltic contractions. This fact is taken advantage of in the giving of *enemas* to flush out the colon and carry off whatever fecal residues may be present, but this is an emergency measure and should not become a regular practice The taking of enemas does not remedy any of the causes of constipation.

If the *diet* is of the type which will provide a relatively soft and bulky intestinal content, if the *nervous factors* are so regulated as to be favorable, and if the *intestinal muscles* are kept in proper tone, satisfactory excretion through the intestine should take place regularly with as little attention as is devoted to the other body processes

DIETS FOR PREVENTING CONSTIPATION

Although diet is by no means the only factor to be taken account of in constipation, it is nevertheless impossible to secure satisfactory intestinal hygiene unless a suitable diet is taken. The diet must include enough indigestible fiber, so that there will be a residue in the intestine *of sufficient bulk and of soft, semisolid consistency to be readily moved* along and evacuated A diet that consists almost entirely of low-residue foods will result in a small amount of hard, dry fecal material, which is difficult to propel, irritates the intestine without stimulating to defecation, and thus tends to remain too long in the colon. It has also been shown that diets of low mineral content (especially those poor in calcium) lead to stagnation in the colon (intestinal stasis) [6] The need for B vitamins in the diet in order to maintain proper muscular tone of the intestines has been *emphasized in the section on vitamins* (*page 225*).

Types of Constipation

There are two kinds of constipation which are caused by diametrically opposite conditions and hence require exactly *opposite types of treatment.* In *atonic* constipation, the infrequency of bowel movements is primarily due to *poor muscle tone* and *sluggish muscular contraction* of the colon. In *spastic* constipation, the circular muscle fibers in some

[6] Robertson, E C, and Doyle, M E, "Intestinal Stasis in Low Mineral Diets," J. Nutr, 9, 553, 1935, Robertson, E C, "Calcium Deficiency and Intestinal Stasis," J. Nutr, 15, 67, 1938.

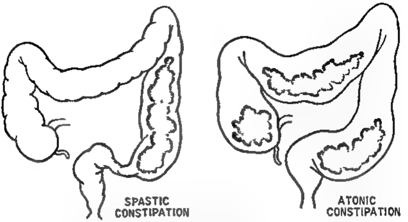

Figure 133. The colon in spastic and atonic constipation. Note the spastic constriction in one case, which blocks passage of feces into the rectum, and the flabby, engorged appearance of the colon in atonic constipation.

lower section of the intestine go into a *spasm of contraction*, either because of irritation from within or because of a general nervous condition, so that the passage of fecal material is *blocked* for a time. In this case all food irritating to the sensitive intestine must be avoided, whereas in constipation of the atonic type fibrous and even harsh foods may be helpful in stimulating the sluggish colon to greater activity.

It is of fundamental importance to distinguish between these two types of constipation in planning the diet. The simplest way to differentiate lies in finding out whether the constipation is *aggravated* or *benefited* by taking a good deal of *fibrous* food, especially that which contains fiber in the rougher forms.

Diet in Atonic Constipation

Since, in this type of constipation, the colon is muscularly sluggish and fails to evacuate feces with desired frequency, the corrective diet aims to add bulk to the food residues, tone up intestinal muscles, and stimulate muscular activity of the colon. Hence, one of the prime objectives is to include foods that contain considerable cellulose or fiber. Such high-residue foods (see lists on p. 137) are *fruits and vegetables*, whole grain breads and cereals, legumes and nuts. All fruits and vegetables contribute needed minerals and vitamins (along with fiber), while whole grain products, legumes, and nuts are among the best sources of the B vitamins needed for good tone of intestinal muscles. More fiber and the harsher types of fiber usually stimulate the muscularly sluggish colon to empty without undue irritation. Harsher types of fiber are found in dried fruits and legumes, seedy fruits and fruit skins, coarse fibered, leafy, and raw vegetables (e.g., green salads), or even the outer coats of cereals as in *bran*. Bran may be sprinkled on breakfast cereal or used

in bran muffins. However, the use of bran may easily be overdone and it is best limited to obstinate cases of constipation which fail to respond to liberal use of fruits and vegetables If bran is irritating to the intestinal tract, *agar-agar* may be taken to add bulk to the feces and keep them soft, it is a shredded preparation of cellulose from seaweed, which is not only indigestible but takes up water and swells to form a soft, gelatinous mass Psyllium seed is another indigestible substance sometimes used to give bulk to intestinal residues Since these substances have no food value, it is best to try to correct constipation by increased amounts of fibrous foods which also carry minerals and vitamins. Obviously, the diet must also contain foods which will satisfy the requirements for protein and energy in order to be adequate

Other adjuncts, which may be of some help in combating constipation, are foods that ferment, extra fats, and acid fruits. Fermenting foods act by creating minute gas bubbles that give food residues of greater bulk and soft, foamy consistency. Acids which are a by-product of fermentation may also help keep down putrefactive bacteria and stimulate peristalsis slightly Fruit acids, such as in lemons, grapefruit, grapes, plums, and rhubarb, act in the same manner. The presence of undigested fat in the colon acts as a lubricant, while fatty acids produced in the digestion of fats may stimulate muscular movements of the intestine The use of foods that ferment (honey, molasses, jams, milk sugar, maltose and dextri-maltose) and of high-fat diets is somewhat limited Many persons with atonic constipation are overweight, so these foods of high fuel value are ruled out, others either digest fats so well that their lubricating effect is lost before they reach the colon or experience intestinal upsets from too much of fermenting foods or high-fat diets Two non-food substances sometimes used to produce these effects are *yeast* (for fermenting action) and *mineral oil* (for lubricating), both are best kept for emergencies. The regular use of mineral oil (a petroleum product, not a true fat) is discouraged and its incorporation in foods (e g, salad dressings) is forbidden in many states, because of the fact that it takes up in the intestine fat-soluble vitamins (and provitamins) and interferes with absorption of certain minerals, thus robbing the body of these nutrients in foods. Live yeast cells also take up B vitamins from the food material in the intestine, thus making them unavailable for the body If the effect of B vitamins in combating constipation is desired, it is better to take *dried* brewer's yeast (dead cells) or wheat germ, mineral oil is best reserved for occasional use as a laxative and taken before retiring (as far as possible from mealtime). Acid fruits or fruit juices may be used as freely as digestion permits, a glass of diluted lemon or grapefruit juice taken a half hour before breakfast is often a useful laxative.

Water is one of the best lubricants, provided enough of it is taken so that it is not all absorbed from the alimentary tract, it helps to keep

the feces soft and bulky Probably the greatest laxative effect is obtained by taking one or two glasses of plain water, or with a little salt added, immediately on rising This tends to pass quickly along the alimentary tract and, in conjunction with the breakfast later, to stimulate the colon to its normal after-breakfast evacuation.

Diet in Spastic Constipation

Foods that are in any way irritating to the sensitive intestinal tract must be avoided in constipation of the *spastic* type Hence *low-residue foods* of *smooth, bland* nature constitute a large part of the diet However, one must use every opportunity to introduce *some fiber in softer forms.* Raw fruits or vegetables, those toughened by drying, those with hulls, skins, or seeds, old or woody vegetables, acid fruits, and much fatty food are not well tolerated by people with spastic constipation Juice or pulp of the milder fruits, strained pulp of cooked vegetables and fruits, and a few of the less fibrous vegetables (cooked but unstrained) are the best forms in which to give fiber

Usually whole grain products are not tolerated, although sometimes they are if flour is very finely ground or cereals are thoroughly cooked and strained So-called "entire wheat" flours are obtainable from which the bran has been removed in milling, but which retain the germ rich in B-complex vitamins They are often mixed with 50 per cent white flour in bread If *no* whole grains can be taken most of the highly milled (white) bread and cereals used should be of the "enriched" variety In addition, some B-complex concentrate (in fluid, tablet, or capsule form) may be needed and taken with advantage

Vegetables like spinach may sometimes be tolerated, provided they are finely chopped or made into a smooth purée, some who do not think it possible could take a few tender leaves of lettuce, if thoroughly chewed Meats or tender beets and carrots may need to be finely chopped Every effort should be made to take fiber in whatever forms are possible, and small amounts taken not too close together will often be well tolerated when larger amounts or more frequent use would cause trouble Prune or tomato juice (strained), or orange juice if not taken with meals, may also be useful and well tolerated

Persons with spastic constipation vary a good deal in their tolerance for different foods As the intestine becomes less sensitive through treatment and limited diet, the diet may gradually be made more liberal by introducing from time to time small amounts of some previously denied foods, but those which are known to be very harsh or irritating should be permanently avoided by persons with a sensitive intestine

If more bulk is needed than can be given in the food, *agar-agar* should be taken in amounts required to produce normal bowel movements Strong cathartics should be avoided in spastic constipation

Table 19. Summary of Diets for Two Types of Constipation

Spastic Type	*Atonic Type*
Smooth, bland foods Milk Eggs Tender meats Cream soups Well cooked cereals Bread and toast Simple desserts	Foods needed for energy, protein and mineral elements to give adequate diet *Substances that stimulate intestine* Acid fruits or fruit juices Acid or fermented milks Foods which ferment Dried brewer's yeast
Fiber in soft forms Stewed fruits, mild ones eaten without skins or seeds Apples Prunes Pears Apricots Peaches Juices or pulp of mild, raw fruits Oranges Peaches Melons Bananas Milder vegetables, cooked (puréed or strained, if necessary) Potatoes Spinach (young) Asparagus tips Cabbage (young) Cauliflower Carrots (young) Broccoli Beets (young) Tomatoes (cooked) String beans (young)	*Fiber in harsher forms* Fruit—especially Raw fruits Dried fruits, raw or cooked Seedy fruits, and those eaten with skin on Raw vegetables Lettuce Radishes Celery Tomatoes Cabbage Carrots Cucumbers Onions Harsher vegetables, cooked Beans, Peas } especially dried Kale Corn Chard Parsnips Greens Turnips Spinach Salsify Brussels sprouts Kohl-rabi Onions
Agar agar	Other vegetables and salad greens Whole grain breads and cereals Bran

Table 19 above summarizes the sharply contrasting diets used for correcting the two kinds of constipation

QUESTIONS AND PROBLEMS

1. What two products of metabolism are excreted through the lungs? Explain how, in the functioning of the lungs, it is possible for these two substances to pass from the blood into the air that is expired When a man exercises, there is increased oxidation of fuel foodstuffs and hence increased production of carbon dioxide. How is this sudden excess of carbon dioxide excreted?

2 What is the chief product of metabolism excreted through the skin? What other substances are present in perspiration? After occurrence of profuse perspiration, why is it advisable to take not only plenty of water but small amounts of salt (sodium chloride)?

3 What waste products are excreted through the kidneys? In a normal person, what conditions will cause an increased or a decreased output of each of the following in the urine—water, urea, sodium chloride,

ammonium salts? Is urine normally acid or alkaline, and what will cause its reaction to vary?

4 What is meant by the water balance of the body? Explain how the body is normally kept in equilibrium as to its water content

5 What are the main constituents found in the feces? Which of these may be described as residues (or debris) from the contents of the digestive tract, and which are true waste products of metabolism? Describe the mechanism that leads to defecation and outline the chief causes of constipation Distinguish between the atonic and spastic types of constipation

6 Write a day's menus suitable for a person with atonic constipation, and another set of menus suitable for a person suffering from constipation of the spastic type Suggest changes in living habits or any other procedures that might be helpful for each of the two types of constipated persons What are the criteria for deciding whether a person is constipated?

SUPPLEMENTARY READING

Physiology Texts, for chapters on the Kidneys and Secretion of Urine

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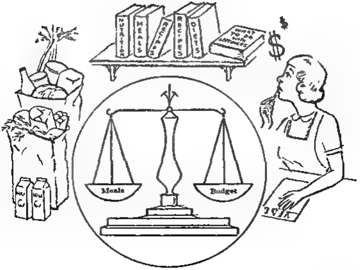
PART THREE

Meal Planning



CHAPTER TWENTY

Making Menus

WHY IS MENU building important enough to deserve a place in a textbook on nutrition? Because it is the means of implementing what one has learned of the guiding principles of nutrition. The housewife may have learned that certain kinds and amounts of food should be included in the daily diet in order that her family should enjoy good health and her children build strong, healthy bodies. But this information may be of little use unless she can present the foods to them in well-liked forms and combined in meals that will tempt the appetite. A "finicky" child may decline to eat the amounts of milk, fruits, and vegetables that the mother knows it should have, or a hungry husband may rebel against the monotony of the meals offered him. The problem of planning attractive meals is the crux of the problem of getting people to take the food which is good for them and *at the same time to enjoy it*.

Moreover, appetizing and attractive meals promote social enjoyment and good morale in family life. Appetite and the mental states that go with the enjoyment of food make for good digestion and assimilation of food, while good meals are often intimately associated with pleasant

Figure 131 Mealtime is a social time for the family and should be fun It is the housewife's privilege and responsibility to plan healthful and attractive meals (Du Pont, "Better Living" magazine)

and stimulating social intercourse The planning of attractive meals is both a *science* and an *art* One should begin by planning the day's meals according to the "*dietary pattern*" given on page 327, see that the kinds and amounts of fruits and vegetables needed for minerals and vitamins are included, that there are enough protein-rich foods and, if possible, some high quality (animal) protein in each meal, if the family habits permit, try to distribute the daily food quota fairly evenly between three meals. Then use ingenuity and art in varying the foods chosen and combining them to give pleasing contrasts of flavor, color, form, and texture.

Every meal-planner has to adapt the meals to the varying tastes and individual problems of her family or budget. Therefore set schemes and arbitrary rules are to be discouraged Menus found in papers and magazines may be of interest for suggesting variety in foods or special ways of serving foods that are plentiful at the time, but must be adapted to individual cases The aim here is to provide the reader with certain *general* rules, which should be kept in mind so as to assure both *attractive* meals and a diet *adequate* to meet body needs. The menus given are merely a few examples of how these meal-planning principles might be applied in practice Since diet for children is considered in a separate chapter, these menus are intended chiefly for normal adults, but could easily be adapted for children.

Let us begin with a few "dos" and "don'ts" for menu-planners Positive rules of what to keep in mind are given below, followed by a brief list of things that should be avoided. On page 415 are given examples of *gross errors* in menu-planning, meals that might be perpetrated if one

ignored the rules given as "don'ts" Below these, each numbered to correspond with the faulty menu that it is designed to replace, are given examples of how these errors might be corrected, *more attractive* and *better balanced* meals, yet retaining some of the key foods used in the poorly planned meals The reader is asked to notice that the substitute

Table 20. Menus Illustrating Bad and Proper Planning

Examples of Gross Errors in Menu-planning

(1) *Too much* PROTEIN	(2) *Too many* RICH *foods*	(3) *Too many* STARCHY *foods too little flavor, monotony in texture*	(4) *Same food used twice, too highly flavored, poor color combination*
Split pea soup Hamburger steak Baked beans Bread and butter Baked custard Almond macaroons	Roast pork Candied sweet potato Fried eggplant Tuna fish salad (mayonnaise) Chocolate blanc mange with whipped cream Cake	Cream corn soup Baked potato Casserole of rice with fish and lima beans Creamed spinach Indian meal pudding	Tomato bisque Roast beef Browned potatoes Buttered beets Tomato salad Raspberry ice Spice cake

(5) *Monotony in texture*	(6) *Monotony in color*	(7) *No satiety value*
Beef broth Creamed chicken Mashed potato Cauliflower Floating Island Sponge cake	Omelette Sweet potato Squash Carrot and string bean salad Lemon jelly	Chicken soup Raw cabbage and pineapple salad Orange Tea

Suggestions of How to Rectify These Errors

(1)	(2)	(3)	(4)
Hamburger steak Boiled potatoes with parsley butter Sliced tomatoes Lettuce salad Bread and butter Apple pie	Roast pork Baked sweet potatoes Stuffed eggplant Lettuce salad Apple sauce Cookies	Beef broth Casserole of rice with cheese and tomato Spinach Waldorf salad Indian meal pudding	Tomato bisque Roast beef Browned potatoes Baked squash Lettuce salad Raspberry ice Sponge cake

(5)	(6)	(7)
Creamed chicken on toast Stewed celery String beans Pineapple salad Floating Island Macaroons	Omelette with asparagus Creamed potatoes Raw cabbage salad Chocolate blanc mange with thin cream Cookies	Cream chicken soup Salmon salad with green peas Bread and butter Orange Tea

menus contain more fruit, vegetables, and raw foods than the original ones, so that they will be more wholesome as well as more palatable

SOME GENERAL RULES FOR MENU-PLANNING

1 Use the *whole day as a unit* rather than the individual meal, have breakfast relatively simple and standardized, then plan dinner, and lastly plan luncheon (or sup-

4 Plan to have in every meal at least one food which has *staying quality* or high satiety value, at least one food which requires *chewing*, one which contains *roughage*, and generally some *hot* food or drink

5 Combine (or alternate) *bland* foods with those of more pronounced *flavor*

6 Combine (or alternate) *soft* foods with those *crisp* in texture

7 Have *variety* in *color*, *form*, and *arrangement* of foods

8 Alternate *simple* and less nutritious dishes with those which are richer, more nutritious, and *harder to digest.*

9 When a greater number of foods are served at one meal, decrease the size of the portions and use fewer rich foods. When a more simple meal is desired, use a few nutritious, easily digested foods, and serve larger portions

DON'TS FOR MENU-PLANNING

1 Do not have a preponderance of *one foodstuff* in a meal.

2 Do not have many *rich* foods, or other foods which are hard to digest, in one meal

3 Do not use the *same food twice in one day* without *varying the form* in which it is served, except staples like bread, butter, milk, etc.

4 Do not use the same food twice in the same meal even in different forms

5 Do not use the same foods too constantly even from day to day.

6 Avoid *monotony* of *color, texture, etc*, in any one meal or in the daily dietary.

PLANNING FOR A DAY

The three meals of the day should always be considered as a whole, planned in advance, and arranged so as to supplement each other This not only is more economical of time and money, but ensures better balanced and more attractive meals, and is the *only way of being sure to get in the full amount of the essential foods each day*

It is best to keep the meals *simple* and to a somewhat standardized pattern When fewer foods are used, it is easier to secure variety from day to day. In general, *the greater variety of foods used from day to day the better for health, but the less the number of foods served at any one meal the better for digestion* And there is no point in multiplying the number of dishes which serve the same purpose for health One will try to include green, leafy, or yellow vegetables often, but two of these in the same meal are no better than a liberal portion of one The staple foods in which one does not crave variety (milk, bread and butter, potatoes, etc.) can be available to use as the appetite and calorie needs of different members of the family dictate The too liberal use of relishes, jams, condiments, and spices is not advised, as it blunts the

taste for the true flavor of raw or well cooked foods, and also may induce overeating

Having a general pattern for the three meals of the day is helpful in planning and avoids a dearth at one meal and a glut at another Of course the pattern must be adapted to the physical needs, as well as to the likes and living habits of the individual or family If one or more members have lunch away from home, the two other meals may need to provide more food and more hot foods than would otherwise be the case If a lunchbox meal is prepared by the homemaker, it should be planned as a meal, and the meals taken at home should supplement it Some people like a light breakfast, but if there is a teen-age boy or a man who does heavy labor in the family, they may wish for and need to have some substantial hot dish or dishes at breakfast If breakfast is light, the other meals of the day should be heavier, going without breakfast is looked upon with disfavor, since mid-morning fatigue is likely to be experienced and it is difficult to get in all the essential foods when only two meals are taken

Breakfast

The pattern for breakfast may vary from light to moderately heavy, according to the physical activity of the persons concerned Most Americans are sufficiently sedentary that their needs are well served with a light breakfast and fortunately the old-fashioned breakfast which included meat and potato, pie or doughnuts, is a thing of the past The practice of beginning the meal with fruit or fruit juice is beneficial both as an appetizer, a laxative, and a way of securing extra vitamins (especially C) A hot beverage (usually coffee) is also helpful to most people in starting the day Hence we advise the inclusion of fruit, some staying food, and a hot drink in every breakfast menu Breakfast is the meal in which people least crave variety, but the rest of the meal may be varied slightly and made more or less elaborate as follows

Light	*Moderately light*	*Moderately heavy*
Fruit	Fruit	Fruit
Breadstuff	Cereal (top milk)	Cereal (top milk)
Hot beverage	Breadstuff	1 or 2 hot foods
	Hot beverage	Breadstuff
		Hot beverage

We may fill in the above menu pattern with foods to make menus, as follows.

Light	*Moderately light*	*Moderately heavy*
Grapefruit (half)	Banana (half, sliced on cereal)	Orange juice
Toast (with jam)	Puffed wheat (top milk)	Oatmeal (top milk)
Coffee	Toasted raisin buns	Fried eggs and bacon
	Coffee	Corn muffins
		Coffee

Luncheon (or Supper)

The size and character of this meal will vary with different individuals and families. If breakfast has been light, a more substantial lunch is indicated (rather than making up by too heavy a dinner), if breakfast has been a fairly substantial meal, the luncheon should be light in order to avoid taking on too much weight. As a general rule, digestion is better when there is at least one hot food with the meal. For luncheon, this may well be either a soup or beverage and the rest of the meal is best kept simple Sandwiches and coffee do not provide a well balanced meal, even for adults, and if a hot meal is served at school, children will get a more adequate diet. If the homemaker prepares the meal, it needs to be simple in order to conserve her time and effort. Sedentary persons need to avoid taking a meal at noon that is a second dinner, or overweight will follow. Only a few persons who do a good deal of muscular work need a substantial meal at midday. For young children, invalids, and elderly people, the heavier meal is best taken at midday and a supper of simple, easily digested foods taken in the evening. Much the same kind of dishes are suitable for supper as for luncheon

Luncheon (or supper) is usually accounted the most difficult meal to plan It is best, in planning the day's meals, to plan breakfast and dinner first, then to make lunch a meal that will carry the rest of the day's quota of essential foods It is the meal *par excellence* for using up left-overs and for securing pleasing variety in salads. Starting with a canned soup, milk or left-over vegetables may be added for extra nourishment, greens and raw fruits may be used in salads, or more substantial salads (shellfish or chicken) may make the main course of the meal, diced meat or creamed vegetables may be served on toast. The following meal plans illustrate how lunch may be varied from a light to a heartier meal:

Light		*Moderately light*		*Heavier*
Soup	Salad	Soup	Hot dish with vegetable	Soup
Salad	Dessert	Salad	Salad	Main dish with vegetables
Beverage	Hot beverage	Dessert	Dessert	Salad or dessert
		Beverage	Beverage	Beverage

The above meal patterns may be filled in to make the menus given on page 419 Notice that foods used for luncheon may include cream soups, egg or cheese dishes, light dishes made from left-overs, vegetables, raw foods in salads, simple desserts, and fruits If this is done, the day's food intake may be made more nearly "optimum" and not just "adequate."

Light		*Moderately light*		*Heavier*
Cream of mushroom soup	Canned peach and cottage cheese salad	Beef broth	Omelette with asparagus tips	Vegetable soup
Apple, celery, and nut salad	Chocolate pudding	Tuna fish salad	Lettuce and tomato salad	Minced beef with gravy on toast
Bread and butter	Coffee	Bread & butter	Graham muffins	Beets, with beet top greens
Milk or tea		Canned apricots with cookies	Applesauce or fresh fruit	Gingerbread
		Coffee or milk	Tea or milk	Milk

Dinner

This is essentially the *social* and the *meat* meal of the day, and as such it is best taken in a relaxed manner after the day's work is over It tends to be a slightly more formal meal and is more attractive if served in separate courses However, there is a tendency towards fewer courses and less formality than formerly (even to the simplicity of barbecued meals) and the elaborate, many course dinner is seldom served now in homes, except sometimes among wealthy families or at banquets There is physiological reason for the arrangement of courses at dinner Soup (especially meat broth) stimulates the flow of digestive juices without blunting the appetite, meat and vegetables (the heaviest load) arrive at the peak of digestive processes, while lighter foods such as salads, sweet dessert, or fruit make a pleasing finish for the meal If the first part of the meal does not contain many rich, hard-to-digest foods, a richer dessert may be served The meal should not include too many rich foods or be taken too late in the evening, for in such cases digestion is apt to be poor and the night's rest disturbed

A very simple dinner will consist of meat and vegetables (which may be combined in a single dish if desired), bread and butter, and a salad or dessert Various appetizers may be included and, in some parts of the country, a light salad (e g , fruit salad) is served early in the meal as an appetizer The number of courses and of foods in one course may be multiplied as desired This is shown in the following types of meal plan

Light	*Moderately light*	*Heavier*
Meat course	Soup	Appetizer
Salad	Meat course	Soup
Dessert	Salad	Meat course
Beverage	Dessert	Salad
	Beverage	Dessert
		Beverage

The may be filled in to make the menus given on p 420 Note that, while all the dinners furnish enough foods for a satisfying meal, the first menu uses mostly foods of lower caloric value, the second is moderate, and the last contains so many foods which are rich and of high caloric value that omission of some or substitution of lower calorie soup or dessert would probably be advisable

Light	*Moderate*	*Heavier*
Broiled ground steak (or meat loaf)	Scotch broth	Fruit cup, banana, orange, and grapefruit
Boiled potatoes	Baked bluefish	Cream asparagus soup
Boiled onions	Baked potatoes	Roast lamb, with brown gravy
Green salad, French dressing	Baked yellow squash	Browned potatoes
Prune whip	Half pear, garnished with raisins	Carrots and peas
Coffee or milk	*Apple pie*	Mixed green salad, Roquefort cheese dressing
	Coffee or tea	*Spanish cream,* chocolate sauce
		Cookies
		Coffee

PLANNING FOR A WEEK

It is a great advantage if the housewife can plan meals for the week, except for last minute alterations. She is thus able to market more efficiently (two trips to a large market usually suffice and she can watch for bargains on special days), to plan for foods that will carry over for several meals (such as a meat roast or chicken), and to effect economy of labor in preparing meals. The family may also profit nutritionally from more evenly planned meals. Nowadays a good many women combine a part or whole time job with being a homemaker, and for them careful planning ahead is especially important, if their families are not to suffer from poorly prepared, inadequate, or monotonous meals. They, as well as other housewives, find that buying in larger quantities and keeping foods ahead in a "deep-freeze" is economical, saves trips to market, and is useful in emergencies Ready prepared, frozen vegetables are also a great convenience, as are baking and pudding "mixes," but whole ready prepared meals (such as TV dinners) are seldom to be recommended Planning oven-cooked (slower) meals for two days of the week, with left-overs which can be used for assembling a quick dinner on other nights, is much to be preferred.

The use of left-over foods is no disgrace, in fact it indicates good planning for economy of money, time, and labor. With modern refrigeration, there need be no question of spoilage if foods are kept in covered dishes or otherwise kept from drying out (aluminum foil wrapping) in the refrigerator If a day is allowed to intervene and they are presented in some quite different dish, they are often better liked at the second than at the first serving Roast beef may be served in cold slices, as a quick stew by warming with gravy, or ground in patties, left-over chicken may appear cold, as pot-pie, in salad, or in a nourishing chowder. Potatoes need not be cooked for each dinner but are relished in numerous warmed-up forms. Fresh vegetables, however, are best cooked only in quantities expected to be eaten at one meal, as they lose vitamins when stored and reheated. Americans throw away much food which should be saved and utilized—scraps of bread or bread crumbs that could be used in casserole dishes or puddings, meat and vegetable trimmings

good for soups, etc, etc With the cost of living so high and much want in other parts of the world, wastefulness is a luxury we can ill afford

The introduction of variety in the planning of menus is the phase that is most troublesome to the average housewife Our grandmothers might have been excused on this score, since at some seasons of the year fresh fruits and vegetables were almost nonexistent and other foods were in scant variety, they used great ingenuity in making the limited variety of foods into many and quite different dishes It would seem that trips to the modern super-markets, with their enormous range of fresh, canned, and frozen meats, vegetables, and fruits, not to mention packaged foods, would be enough to stimulate the imagination of the modern homemaker Perhaps from force of habit, some still go on using only the same five meats and six vegetables as they have been doing for years It does not seem to occur to them to buy broccoli instead of string beans, yellow squash instead of carrots, or ground veal for veal loaf instead of ground beef for hamburgers And pleasing variety may be obtained by different ways of cooking and serving the same food Celery, which is usually served raw, can also be boiled and served with cream sauce, or can lend flavor to a dish of chop suey, apples are one thing raw and crisp, quite different in applesauce, in Brown Betty pudding or apple pie There are said to be a hundred ways of cooking and serving chicken So the modern housewife not only needs to keep her eyes open in the grocery store but to sit down with a good cookbook, when planning her menus for the week

We cannot give time and space here to menus for a whole week, but will content ourselves with following the various appearances of Sunday's roast chicken through Tuesday, to the serving of a new meat mainstay on Wednesday, which can in turn provide left-overs for meals later in the week, if desired Other foods that appear in more than one guise are celery, apples, apricots, eggs, and cheese The Sunday and Tuesday dinners are chiefly cooked in the oven, those for Monday and Wednesday on the top of the stove (to conserve labor and fuel). Perhaps we have used foods in cream sauces too frequently for some tastes, but this is one of the easiest ways of introducing more milk into the daily fare for those who do not drink it, any of the day's quota not used in or on foods should be taken as a beverage (see below for list of ways of using milk) Baked desserts may be made when the oven is in use for other foods and other desserts may be prepared ahead of mealtime

Ways of Using Milk

As a beverage— [illegible]

In soups—cream soups, chowder, oyster stew, etc
In desserts—puddings, custards, ice creams, etc

Menus Planned for a Four-Day Period

Sunday	*Monday*	*Tuesday*	*Wednesday*
Breakfast			
Orange juice Scrambled eggs and bacon Toast Coffee or milk	Baked apple Cornflakes Muffins Coffee or milk	Tomato juice Oatmeal Toast Coffee or milk	Whole orange Puffed wheat Muffins Coffee or milk
Luncheon			
Peanut butter, lettuce, and fresh tomato sandwiches Cocoa (thin, with milk) Raw apples	Chicken soup Creamed celery on toast Pineapple and cottage cheese salad Cookies and milk	Boiled eggs, diced, with cream sauce Green peas Lettuce salad Canned apricots Plain cake	Macaroni and cheese Carrot sticks (raw) Baked custard Cookies
Dinner			
Bouillon Chicken, roasted Sweet potatoes, baked Creamed onions Celery hearts Caramel blanc mange, with cream Coffee or tea	Lamb chops Hashed brown potatoes String beans Mixed green salad Cabinet pudding with lemon sauce Coffee	Cream asparagus soup Chicken pies (individual) Baked potatoes Brussels sprouts Raspberry jelly, whipped cream Cookies Coffee or tea	Vegetable soup Pot roast of beef Boiled potatoes, with brown gravy Cauliflower Mixed vegetable salad Apricot whip Plain cake (or cup cake) Coffee, tea, or milk

PLANNING FOR THE SEASON

This includes two phases of meal planning, (1) using foods that are especially plentiful and relatively inexpensive at certain times of the year, and (2) making certain adaptations of the diet to suit hot or cold weather

Foods that are *plentiful only at certain seasons* are chiefly the fresh fruits and vegetables, although eggs and certain meats may be scarcer and more expensive at some times of the year In the large cities, one can often get out-of-season fruits and vegetables almost the year round, but at fancy prices since they are either hothouse grown or must be brought from long distances Oranges, apples, bananas, tomatoes, lettuce and certain other green vegetables are staples which can be obtained the year round, but even so there are seasons when they are cheaper and of better quality. If we do not take advantage of fresh berries, peaches, pears, grapes, and melons in season, we are likely to have to fall back on canned ones or do without It is a pity to miss the flavor of various fresh foods and, when they are in the market in great plenty, one may well use them extra freely. Since they are seasonal, there is little danger of our tiring of them even if they appear on the menu daily or even twice a day for a time.

Menus For Summer And Winter

Summer		Winter	
Breakfast			
Raspberries Puffed rice 1 boiled egg Toast Coffee or milk	Orange juice Shredded wheat Coffee cake Coffee or milk	Stewed figs Graham mush Toast Coffee or milk	Grapefruit Griddle cakes Sausages Toast Coffee or milk
Luncheon			
Creamed chicken on toast Green salad, French dressing Jelly sandwiches Cup custard Iced tea	Fresh fruit salad, cream dressing Brown bread sandwiches with cream cheese Cocoa, tea, or milk	Macaroni and cheese Stewed tomatoes Applesauce Gingerbread Tea or milk	Oyster stew, with crackers Sliced ham, cold Creamed peas Baking powder biscuits, honey Canned peaches
Dinner			
Bouillon Cold tongue, sliced Potato salad Fresh tomatoes, sliced Ice cream or sherbet Cake Coffee	Jellied consommé Minute steaks Boiled potatoes Broccoli au gratin Tomato aspic salad Iced melon	Chicken soup, with rice Pork chops, breaded Creamed spinach Chocolate bread pudding with creamy sauce Coffee or tea	Tomato soup Braised beef, with potatoes and carrots in gravy Succotash Green salad Mince pie Coffee

And the liberal use of fresh fruits and vegetables fits in perfectly with the type of diet that is needed for *hot weather* Everyone knows from experience that on hot days the appetite is less and digestion is easily upset, so that less food and easily digested foods are indicated Since one is losing much water through the skin in the effort to cool off the body, plenty of water should be taken Nothing is more refreshing than a long glass of lemonade or iced tea with lemon, or some other fruit drink Since one exercises less in hot weather, fewer calories are needed, and one craves the cooler, lighter foods Although it does no harm to eat very lighty for a few days during a "hot wave," in the long run the summer diet must supply enough foods that provide protein, minerals, and vitamins, as well as calories, to meet the body needs Some meat, milk, eggs, and vegetables must be included in the diet, along with the fresh fruits and *salads* The housewife should plan not only to provide foods that are acceptable in hot weather, but also to spare herself work in a hot kitchen by reducing cookery to a minimum The types of dishes that combine well to make a summer diet are illustrated in the menus given above on this page

In *winter*, those who are outdoors a good deal will use more food and can handle more rich and fatty foods than at other seasons Even those who spend most of the day in heated rooms will find a spell of

cold weather stimulates the appetite and involuntarily makes them move more briskly. Hot foods are welcome and most people eat at least a little more heartily. Such foods as griddle cakes and waffles, sausages and bacon, pork and meats with rich gravies, rich steamed puddings, doughnuts, and pies appear on the menu. Yet the winter menu also should include its quota of milk, vegetables, and fruits; the vegetables may be used that are less expensive in winter (e.g., the root vegetables) and dried or canned fruits can eke out the smaller number of fresh fruits that are reasonably priced all year long. Two sample day's menus suitable for winter are given on page 423.

QUESTIONS AND PROBLEMS

1. Why is menu-planning important? What should be the unit for planning menus—the meal, the day, or the week? Why? In what respects is menu-planning a science and in what respects is it an art?

2. Tell in what respects the following menu is faulty and make suggestions by which it may be improved:

Cold sliced salami sausage
Potato salad
Crackers and cheese
Apple pie
Beer

3. Why is it impractical to provide variety by serving many different foods in one meal or day? Why is use of a wide variety of foods from day to day, or week to week, good nutritional practice? How can sufficient variety be made consistent with the use of left-over foods? What would you say is the "golden mean" as to variety in meals?

4. Plan a day's menus for a moderately active college student, who should have a fairly hearty breakfast, a moderate lunch, and a hearty dinner. Check these menus with the list of essential foods (foundation diet, page 327), and rules for menu-making given on page 416.

5. Make a day's menus for a young married couple, both of whom work and eat lunch away from home. Plan for a moderate breakfast and a fairly hearty dinner, both of which are quickly prepared. Keep food costs as moderate as is consistent with providing adequately for their nutritional needs.

6. Suppose that this couple has invited two other couples for dinner. For this occasion, they may buy some more expensive foods or some that are ready to serve, since the wife prepares the meal. Plan a menu for such a dinner, assuming the party takes place on a hot summer evening. Make another dinner menu suitable for a cold night in winter.

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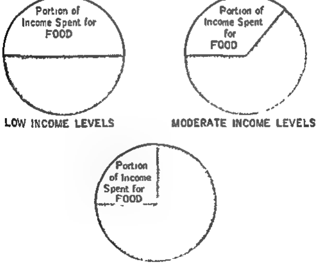
Family Food Budgets

WHO SHOULD be interested in food costs and why? The answer to the first part of this question is "practically everyone" In the early days of this country, when both food and money were scarce, everyone was taught the virtues of thrift, not only did this permit people to have a pretty good diet at moderate cost but it allowed families to save for the future Nowadays, when both foods and money are abundant, thrift is forgotten and we talk chiefly about the "good life," which often means more and better food, more gadgets, more leisure and ways to spend money on pleasure. In this era of relative prosperity and extravagance, many families spend more for food than they need to and more than is justified if the other needs of the family are to receive due consideration High cost does not always mean the best food in the physiological sense, and simpler, less expensive foods are often more wholesome. Overindulgence in food, with resultant overweight, is only too evident as one watches people in any crowded place

What Proportion of the Income Should Be Spent for Food?

It is of vital concern not only to families but to the nation that there should be sufficient income to purchase the kinds and amounts of food needed to maintain health. The social welfare and productivity of a nation depend on its citizens being well fed, since health, happiness, and earning power all are dependent upon food that will supply all the body needs. In underdeveloped countries, the class of citizens unable to buy enough food to maintain satisfactory health is unfortunately large. Here it is fortunately small, but still with us in some city slums, on struggling small farms, among the unemployed, in families where the breadwinner is ill, among old people and those trying to subsist on small pensions. Many of these require some assistance from the government or from social welfare agencies.

In general, the *less the income the greater the proportion of it that must be spent for food in order to secure a nutritionally adequate diet.* An American family at a low income level may have to spend from *one-half to two-thirds* of their total income for food in order to obtain a *"minimum-cost adequate diet."* At very low income levels, even the most



necessary expenditures for clothing and housing may rob a food budget that is already low so as to make it inadequate to maintain health. A mass of statistics goes to prove that among such families we find higher death rates (especially among young children and pregnant women), more sickness and absences from work or school, and smaller relative growth of children, than we do in families at higher income levels. So it is of vital importance for such people to learn how an adequate diet may be secured at the lowest possible cost It requires careful selection of foods, economical buying, and control of waste in the home to obtain an adequate diet on a very limited amount of money.

At moderate income levels (about $3,000 to $6,000 yearly for a family of four, according to government agencies) from *one-fourth to one-third* of the total funds would need to go for food in order to secure a "*moderate-cost adequate diet.*" Even so, it requires careful selection and buying to secure this standard of diet at this price level, and it offers few "frills" At present (1959), it seems that many middle class families spend about $12 per person per week for food, which for a family of four means a food budget of about $2,500 per year. Unless their incomes are higher than those quoted above, they have preferred to get a better, or at least a more pleasing, diet by spending nearer one-half than one-third of their money on food. By wise meal planning and use of some cheaper yet equally nutritious foods, perhaps less could be spent on food and more money be left for other needs of the family.

At higher income levels, one may not need to spend more than *one-fourth* of the income for food in order to purchase what is termed as a "*liberal diet*" The student of nutrition will, of course, recognize that this does not mean more liberal as to calories (since overeating as to calories carries a penalty) but it does imply that certain foods of relatively higher cost (most of which carry nutritional values) may be provided more freely, these include the so-called "protective foods"—milk, eggs, fruits and vegetables, also probably either more or higher-cost meats. The greater freedom of choice will insure a better diet nutritionally only if wisely exercised, for the higher cost foods are not necessarily those best for health A so-called "luxury consumption" of meats, rich foods and sweets does not make for health and we still find some cases of malnutrition in families where there is plenty of money for food. However, there is certainly less malnutrition and its resultant ill health when the money spent for food is liberal than when it is scanty

Factors Which Affect the Price of Foods and Amount of Food Budget

Whether a food is relatively high-priced or low-priced, depends chiefly on the law of supply and demand, the cost of production, and the costs of transportation, preparation, packaging, marketing, etc. Foods that are scarce or out-of-season always are relatively higher priced, those that are staples, keep well, and are in constant den

Choice cuts of meat are higher priced because the amount of them is small in proportion to the whole carcass and everyone wants them, meat of any sort is a relatively high priced food because it costs a good deal to raise and feed animals, and production costs also influence the prices for eggs and milk To these must be added the cost of transportation and getting the food to the consumer in good condition (refrigeration of perishable foods) Peaches or apples from Oregon, or lettuce from Georgia, will cost more in New York City than the same foods locally produced. Precooked and fancily packaged foods (especially in small packages) are relatively expensive Some much advertised brands are no better than lower priced ones produced by smaller firms that do not advertise widely. Cash-and-carry groceries can sell at lower prices than groceries that deliver and carry charge accounts Large chain stores often package and market their own brands of staple foods at reduced prices, and all stores offer special "bargain days" for certain foods they wish to "move" in quantity

The size of the family food budget will depend chiefly on the following factors

(1) the size and character of the family,
(2) where they live, and
(3) the amount of food produced or preserved at home

It is obvious that it will cost more to feed four persons than one or two. A family of two adults usually has the most leeway as to the amount to be spent for food, while the larger family, especially if there are several growing children, has to spend not only a larger amount but a larger proportion of their income for food Young children and rapidly growing teen-agers need a larger allowance of certain foods that are relatively more expensive (such as milk, meat and eggs for good quality protein, and fruits and vegetables for minerals and vitamins) In certain sections of the country (North Atlantic, Mid-western, and Pacific-coast states) the cost of living is higher than in other parts (especially the Southern states) City food costs are higher than in small towns, and when one lives on a farm and can produce part of the family food supply, the money spent for food is naturally less Canning or otherwise preserving (e g, deep-freeze) foods that are plentiful in season for use at times when they are scarce always saves money

At present one factor looms more important than any other in its effect on the cost of foods, and hence the amount that must be spent to purchase an adequate diet Thus is the *fluctuating purchasing power of the dollar* Whatever the numerous causes of inflation, we are all very conscious that a dollar will buy much less in food, other commodities, or services than formerly To dramatize this point, the chart on page 430 gives a curve which shows the cost of the same kinds and amounts of foods (those in the "market basket") at intervals from 1928 up to and

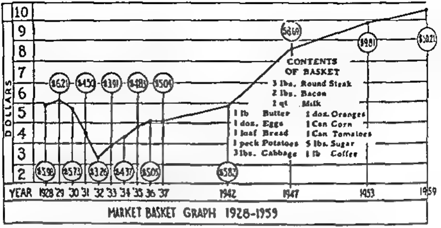


Figure 136 Fluctuations in purchasing power of the dollar, as shown by relative costs of the items, listed as contents of the basket, in different years It cost 102 per cent more to purchase these items in July, 1959, than in July, 1937 (based on average U S city prices as reported by the Bureau of Labor Statistics).

including June, 1959 Prices are from the average retail prices in nearly 50 large and small cities in the United States, as reported by the Bureau of Labor Statistics From the low point on the curve, in 1932, the cost of these food items has risen steadily. The cost of these same foods, as of June, 1959, is double what it was in 1937 (up 102 per cent), 18 per cent higher than in 1947, and 4 per cent more than in 1953 Thus the food dollar will now buy less than half as much as its average purchasing power in the 1935–39 period Such high food prices are due to inflation rather than to any scarcity of food In spite of high prices, the American people are eating more of almost all classes of food than before World War II.

Because it is impossible to tell how much foods will cost at any given time, it is imperative that a discussion of food costs should be on a *relative cost basis* Even if the general level of prices goes up or down, certain *kinds* or *classes* of food are always less expensive than others Then we have to take into account what return in nutritive essentials is obtained by equal amounts of money spent for different types of food Foods that provide mainly calories are usually the cheapest to buy, protein is more expensive but we may buy it either in more or less costly foods, while again we may buy vitamins and minerals in foods that furnish them at greater or less cost

The three main *ways of reducing the cost of an adequate diet* are by

(1) using a larger proportion of the less expensive food groups,
(2) substituting cheaper for more expensive foods within the same food group, or
(3) eliminating waste in buying, cooking, or serving foods

Using a Larger Proportion of the Least Expensive Food Groups

Most of us do not need to subsist on a minimum-cost diet, but for those who do the problem is how to make such a diet adequate for body needs. One of the main problems is to get enough fuel foods to satisfy hunger and to provide the energy for work and to keep warm. Instinctively, such people have selected foods that provide energy at the least possible cost and these foods bulk large in any low-cost diet. The diagram in Fig. 137 shows the types of food that will furnish the largest number of calories for the money spent. At the top of the list will be found lard, sugar, margarine, oatmeal or flakes, dried beans, rice, and bread; these typify the cheaper fats and sweets, cereal foods, and dried legumes; to these might be added potatoes, peanut butter, and butter, though none of these are now exactly "cheap." As much as two-thirds of the calories is sometimes furnished by this type of foods in very low-cost diets.

Cereal products and starchy vegetables may be used more safely in

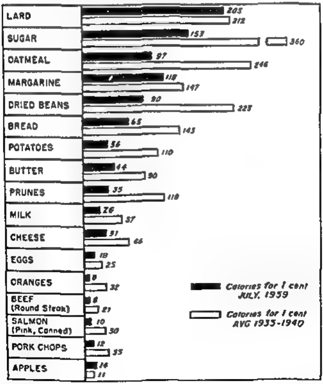


Figure 137. Relative economy of different foods as sources of body fuel, average 1935–1940 prices compared with those of July, 1959 (based on retail prices in forty-six cities, U. S. Bureau of Labor Statistics).

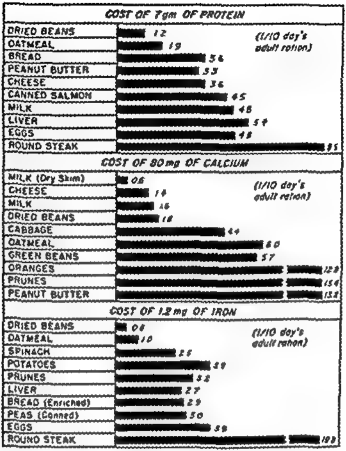


Figure 138 Relative costs in cents of 1/10 of the daily adult allowance of protein, calcium, and iron, as purchased in various typical foods (based on U. S. Bureau of Labor Statistics average prices, July, 1939)

large quantities than sugar or fats, since the latter foods carry nothing but fuel and are apt to provide a one-sided diet, as well as to disturb digestion When cereal products bulk large in the diet, it is important that whole grain or enriched products be used, since these carry a valuable bonus in minerals and vitamins, which the highly milled products do not provide. Sherman has estimated that, if whole grain products and enriched bread are used, these may safely furnish up to 40 per cent of the total fuel value of the diet

Although few of us would want to consume such large amounts of low-cost fuel foods, this method of economizing on food costs is used in most families to some extent. If the budget is low at the end of the month, macaroni and cheese, spaghetti with meat balls and tomato sauce is likely to appear on the menu, or there may be a lunch or supper of bread and milk, or cereal with milk, or the family may simply fill out a rather skimpy meal by eating more bread and potatoes Many a stu-

dent, trying to get through college on a very limited sum of money, has made the mainstay of the diet foods like bread with peanut butter or cheese, or oatmeal and milk, eked out by some orange or tomato juice

On any minimum-cost diet, the foods to choose from are limited and there is not as much variety as most persons like, but if the few foods used are wisely selected, the diet may be adequate for health Some foods must be included to provide the *necessary protein, minerals, and vitamins* Some of those that are cheap sources of energy may also provide relatively inexpensive protein (such as milk, cheese, dried peas or beans, and whole grain cereals), milk, whole grain or enriched cereal products, and legumes all carry important mineral elements and vitamins (chiefly the B vitamins), some inexpensive sources of vitamins A

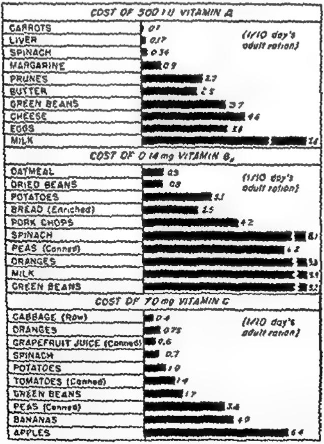


Figure 130 Relative costs in cents of 1/10 of the daily adult allowance of vitamins A, B, and C, as purchased in various typical foods (based on U S Bureau of Labor Statistics average prices, July, 1959)

and C *must be assured for health. In* Figs. 138 and 139, on pp 432 and 433, typical foods that offer the least expensive ways in which to buy protein, minerals, and vitamins will be found at the top of the diagrams The common unit used is the cost of one-tenth of the recommended daily allowance for an adult. It will be seen that by far the cheapest sources of these different essential nutrients are.

PROTEIN	. (vegetable) grain products, legumes (especially dried), peanut butter, (*animal*) *cheese, milk, and cheaper kinds of fish or meat.*
CALCIUM	. cheese, milk (especially dried skim milk), leafy vegetables (except beet tops, chard, and spinach), legumes, and whole grain products
IRON .	legumes (dried or canned), whole grain products, leafy vegetables, liver, potatoes, and prunes
VITAMIN A	leafy vegetables, yellow vegetables, liver, fortified margarine, prunes, and butter.
VITAMIN B_1	. whole grain products, dried legumes, potatoes, enriched bread, and pork
VITAMIN C	raw cabbage, canned grapefruit or orange juice, oranges, leafy vegetables, potatoes, and canned tomatoes

From the foregoing summary, it is apparent why the free use of whole grain bread and cereals, potatoes, leafy and yellow vegetables, legumes, cheese, and milk, is recommended for the low-cost diet. Evaporated or concentrated whole milk is cheaper than fresh whole milk and has the same food value, also dried skim milk is useful as beverage or in cooking to provide animal protein, calcium, and B-complex vitamins at very low cost Since meat is usually the most expensive item of the diet, low-income families are advised to serve cheaper cuts (such as chuck, breast of veal, shoulder of lamb, chopped meat, and stew meat) only three or four times a week, and to use fish, legumes, and an egg or cheese dish on the other three or four days Thus by sacrificing variety and using chiefly the foods that provide good quality protein, minerals, and vitamins at relatively low cost, these nutritive essentials need not be lacking in the diets of low-income families

Substitution of Cheaper for More Expensive Foods in the Same Food Groups

Substitution of cheaper for more expensive food within the same group is another way to reduce food costs and is the *best program to follow where only moderate reduction of food expense is required,* because none of the nutritive advantages of the higher cost diet are sacrificed, e.g , one can have the advantages of using fruits and vegetables *liberally* but keep down cost by selecting only the least expensive *kinds* of fruits and vegetables In a moderate cost diet, the relative *amounts* of milk, fats, flesh foods, and eggs can remain practically the same as in the high-cost diet Considerable reductions in costs may be made, however, by using cheaper substitutes for the more expensive foods in the same group How this kind of food economy may be effected is outlined below:

Grain products—Even in this relatively inexpensive food group some foods are cheaper than others

Corn and rice are usually cheaper than wheat

Home-made *breadstuffs* are cheaper than bakery products, and plain breads are cheaper than those with special flavor appeal Crackers, sweet buns, cake, cookies, and doughnuts are expensive when purchased at the store

At least half of the bread and cereals should be whole grain or enriched

Sweets—*Sugar* is one of the cheapest fuel foods but should not furnish more than 10 per cent of the total calories

and open kettle sugar cane sirup have a *mineral content* especially valuable in a low-cost diet

Jellies, jams, marmalades, and preserves are relatively expensive, but may be useful to render bread and other inexpensive starchy foods more acceptable Home-made jams and jellies are least expensive

Fats

eggs are moderately priced, they are a more economical source of protein than most cuts of meat, but at higher prices eggs rank with round steak for protein value, and the cheaper cuts of meat may be a better buy, *nuts* and most *flesh foods* (meats, fish or shellfish, and poultry) are usually the most expensive of the protein-rich foods

Flesh foods—Within this group there are very great differences in cost levels Certain *fatty meats* may be relatively inexpensive, next come the *cheaper cuts* of red

Fruits—*Dried fruits* (raisins, dates, figs, apricots, prunes, peaches and apples) are sometimes the most economical of the fruits Any of them that are relatively inexpensive (e g , prunes and peaches) should be used in the low-cost dietary

Canned fruits are usually less expensive than fresh, but may not be when a *fresh fruit* is in season and plentiful

Of the *fresh* fruits, *apples, bananas* and *oranges* are apt to be the least expensive, though some of the others may be relatively cheap at the height of their season The *citrus fruits* and *tomatoes* are especially valuable for their vitamin C content, canned orange and grapefruit juices are usually the least expensive sources of this vitamin

Most expensive are the less common fruits and fresh fruits which are out of season

Vegetables—*Potatoes* and the *root vegetables* are usually the least expensive.

and C must be assured for health In Figs 138 and 139, on pp 432 and 433, typical foods that offer the least expensive ways in which to buy protein, minerals, and vitamins will be found at the top of the diagrams The common unit used is the cost of one-tenth of the recommended daily allowance for an adult It will be seen that by far the cheapest sources of these different essential nutrients are:

PROTEIN	.(vegetable) grain products, legumes (especially dried), peanut butter, (animal) cheese, milk, and cheaper kinds of fish or meat
CALCIUM	.cheese, milk (*especially dried skim milk*), *leafy vegetables* (*except* beet tops, chard, and spinach), legumes, and whole grain products.
IRON ..	legumes (dried or canned), whole grain products, leafy vegetables, liver, potatoes, and prunes
VITAMIN A	leafy vegetables, yellow vegetables, liver, fortified margarine, prunes, and butter.
VITAMIN B_1	. whole grain products, dried legumes, potatoes, enriched bread, and pork
VITAMIN C	raw cabbage, canned grapefruit or orange juice, oranges, leafy vegetables, potatoes, and canned tomatoes

From the foregoing summary, it is apparent why the free use of whole grain bread and cereals, potatoes, leafy and yellow vegetables, legumes, cheese, and milk, is recommended for the low-cost diet Evaporated or concentrated whole milk is cheaper than fresh whole milk and has the same food value, also dried skim milk is useful as beverage or in cooking to provide animal protein, calcium, and B-complex vitamins at very low cost Since meat is usually the most expensive item of the diet, low-income families are advised to serve cheaper cuts (such as chuck, breast of veal, shoulder of lamb, chopped meat, and stew meat) only three or four times a week, and to use fish, legumes, and an egg or cheese dish on the other three or four days. Thus by sacrificing variety and using chiefly the foods that provide good quality protein, minerals, and vitamins at relatively low cost, these nutritive essentials need not be lacking in the diets of low-income families

Substitution of Cheaper for More Expensive Foods in the Same Food Groups

Substitution of cheaper for more expensive food within the same group is another way to reduce food costs and is the *best program to follow where only moderate reduction of food expense is required*, because none of the nutritive advantages of the higher cost diet are sacrificed, e g., one can have the advantages of using fruits and vegetables *liberally* but keep down cost by selecting only the least expensive *kinds* of fruits and vegetables In a moderate cost diet, the relative *amounts* of milk, fats, flesh foods, and eggs can remain practically the same as in the high-cost diet *Considerable reductions in costs may be made, however,* by using cheaper substitutes for the more expensive foods in the same group. How this kind of food economy may be effected is outlined below:

for cookery use, (3) loss of nutritive substances by discarding cooking water or liquid from canned vegetables, (4) burning foods or careless scraping of them from cooking utensils for serving, or (5) failure to utilize left-over foods properly. Food may also be wasted at the table by taking too large individual portions or, in one way or another, rendering what is not eaten unfit to serve again. Spoilage of food through improper care in storage is another common form of waste.

There is no sense in purchasing fruits and vegetables, chiefly for the mineral and vitamins, and allowing most of these nutrients to be lost before food reaches the table. The main losses occur through exposure to air or sunlight (either at room temperatures or the higher temperatures used in cooking), and through solution in water. Vitamin C is particularly susceptible to destruction on exposure to air, riboflavin on exposure to light, and mineral salts and water-soluble vitamins to loss by solution in water. Keep perishable foods in a cool, dark place, do not buy fruits and vegetables in too large amounts at a time, prepare them for the table or for cooking as short a time beforehand as possible, and serve promptly. The Bureau of Home Economics made the following suggestions for *minimizing loss of mineral elements and vitamins in cooking procedures*:

Don't stir air into foods while cooking.
Don't put them through a sieve while still hot.
Don't use soda in cooking green vegetables.
In boiling foods, raise the temperature to the boiling point as rapidly as possible.
Use as little water as possible.
Don't use long cooking processes such as stewing when shorter methods are feasible.
Don't throw away the water in which vegetables have been cooked; use it in making gravies, sauces, and soups.
Prepare chopped fruit and vegetable salads just before serving.
Start cooking frozen foods while they are still frozen.
Serve raw frozen foods immediately after thawing.

Distribution of the Food Dollar as an Aid in Planning Diets at Different Cost Levels

The simplest and probably the most feasible way for most housewives to plan adequate diets at different cost levels is to *properly apportion* the amount of money spent among the various *food groups*. We know that each of the food groups is valuable for certain nutrients and that, even in a very low-cost diet, a certain proportion of the money must go for dairy products, fruits and vegetables if all the needed nutrients are to be obtained in satisfactory amounts. How do people usually spend their food dollar and what plans may be a help in securing adequate diets at differing cost levels?

From time to time government agencies have made surveys of the amount of money families of different economic levels spend for food, the foods they buy, and how adequate their diets are at various cost

Cabbage and some of the other *leafy vegetables* in their season are relatively inexpensive.

Leafy, green, and *yellow vegetables* have the highest vitamin A value

Dried legumes are usually cheap, canned vegetables are often moderately priced, and *canned tomatoes* are especially useful to add flavor and vitamins in a low-cost diet.

Frozen vegetables (and fruits) are fairly expensive, but afford variety in moderate cost diets They are without waste and with full nutritive value of fresh ones.

Most *fresh* vegetables (especially the succulent ones) are at least fairly expensive except at the height of their season.

The less used vegetables and those that are out of season are the most expensive of all

Elimination of Waste

This represents the most satisfactory means of all to reduce food costs, since it *involves no diminution in the variety, attractiveness, or nutritive value* of the menu. By merely "stopping the leaks," often enough saving can be effected to provide an even better diet at less cost. Such wastage can occur in the course of buying, storing, preparing, or serving foods and in so many different ways that each housewife must study her own special problems Sometimes the carelessness of the housewife serves to enrich food merchants, or to go down the drain in nutrients lost in cooking water, or to appear in an overflowing garbage pail And people who can least afford such carelessness often seem those most prone to it, while those who have larger incomes may often be thrifty.

Considerable money savings can be effected by *thrifty marketing* Some factors which cause higher costs for foods were discussed on pp. 428–9 (such as extra cost of precooked, specially prepared and packaged foods, small packages, etc). In general, buying in larger quantities, watching for special bargains on certain foods, going to the market to select perishable foods that are of good quality, and selecting less expensive types or brands of food when these are suitable, will all pay off in lowering the food bills. One should plan to use some of the cheaper cuts of meat as often as feasible, for they are just as nutritious as more expensive ones and may be made very palatable if properly cooked Plan to use occasionally the organ meats, fish, or legumes or cheese in place of meat, also smaller amounts of meat may be "extended" by combining with a starchy food, as bread crumbs, noodles, or rice. Watch for the total contents in canned foods, often a can with twice the quantity will not cost very much more than the smaller one With fruits and vegetables, higher price is usually based on appearance and the one at lower price may be well suited for one's use, such as small, tart apples for applesauce

Waste in the kitchen may occur in many ways, some of the chief ones being (1) discarding portions of food which have nutritive value (vegetable trimmings, meat trimmings, fat and bones, etc.) which are suitable for soup, (2) failure to save fats tried out of meats in cooking

Distribution of the Food Dollar

Food Group	*Actual Spending,* Avg Am Family, 1955 cents	*Recommended* For *Low-cost* Diets cents	At *Higher Costs* cents
Meats, fish, and eggs	36	20	25
Milk, cheese, ice cream	15	20	20
Fruits and vegetables	19	20	25
Bread and cereals	10	20	10–15
Fats, sweets, beverages, etc	20	20	10–15

American family[3] However, the proportion spent on dairy products and fruits and vegetables should not be skimped but the difference should be made up by spending less for bread, cereals, fats, sweets, and other items

With this distribution of the food money in mind, the homemaker can start by planning her menus Whatever the size or make-up of her family, or the level of her food budget, out of every $10 spent about $2 50 should go for meat and eggs, the same amount for fruits and vegetables, and at least $2 for dairy products, this will leave only $3 to be distributed between the other types of food In each food group she will have to choose the foods that are priced within the limits of her budget (from low to high cost) She would best start by planning the daily allowances of milk (3–4 cups for each child, 2 cups for each adult), bread and cereals as distributed between the three meals Then, to make sure that the diet is adequate, plan the menus so that each person gets during the day at least one serving of each of the following foods—citrus fruit or tomato, green or yellow vegetable, meat or legumes, some other fruit and/or other vegetable (plus potato, usually once a day) She will soon get adjusted to spending approximately the proper relative amounts for each food group without calculations, or she may check up at the end of a week or month on the total amounts spent for each food group, if she wishes Three sets of a day's menus, planned for low-cost, moderate-cost, and higher priced meals, are given on page 440, as examples of this kind of planning

As these three menus stand side by side, they afford an excellent opportunity of noting the wide price range possible within the same food group By reading from left to right, the reader will note the range from canned orange juice (one of the cheapest sources of vitamin C) to the relatively expensive cantaloupe as breakfast fruit, the range from inexpensive potato and raw cabbage salads to avocado and endive which are quite expensive, the range in meats from small amounts in the casserole dish (made savory with tomato and peppers), through the very moderate priced veal loaf, to the expensive roast beef, and so on with almost every item in the menu As a matter of fact, the highest priced menus use

[3] [illegible]

HOW THE FOOD DOLLAR IS SPENT

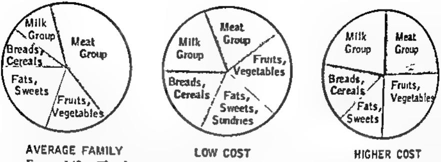


Figure 140 The divisions in the first circle (average family) indicate the relative amounts spent for the different food groups, actual distribution of the food budget as determined by surveys At all income levels, by far the greatest expenditure was for meats, with less than optimum amounts spent for dairy products, fruits and vegetables The other two circles represent recommended distribution of the food dollar between food groups at low and higher income levels

levels.[1] According to the latest survey (1955) the average family divided its food dollar thus 36 per cent for meat, poultry, fish and eggs, 15 per cent for milk and milk products (other than butter); 19 per cent for potatoes and other vegetables and fruits, 10 per cent for bread and other grain products, the remaining 20 per cent for fats, sweets, beverages, and all other foods This pattern of spending did not vary much at different income levels It will be seen that the expenditure for the meat and eggs group was by far the highest, with fruits and vegetables next, and only ⅙ and ⅒ of the food dollar spent for dairy products and grain products, respectively Gillett[2] has suggested that *low-cost* diets will be nutritionally more adequate if the food money is divided approximately into *fifths*, thus giving greater prominence to dairy products and fruits and vegetables, and less to the meat group (see second column of the table on page 439) When a larger amount can be spent for food, the proportion spent for grain products, fats, and sweets may well be cut down, allowing more to be spent for meats and for fruits and vegetables, with expenditure for dairy products at the same level (see recommended distribution in the third column of the table) With the high prices for meat and eggs at present, it may be necessary that about ¼ of the food money go for this group in order to have a diet that will satisfy an

[1] Surveys of family food purchases were made in 1937, 1948, and 1955, by regions and averages for the country as a whole Those for the country as a whole, in the ... "Food Con- ... 1, and ... No 6, ... 5 cents ... st) are ... -57

Table 21. Amounts of Various Food Groups Recommended Weekly for Various Members of Family Group and Totals for Family of Four

Food	*Man*	*Woman*	*Child*		*Totals*
			8 Years	*10 Years*	
Milk	5 qt	5 qt	6½ qt.	7 qt	21½ qt.
Citrus fruits, etc	2 lb 8 oz	2 lb 8 oz	2 lb 8 oz.	2 lb 12 oz.	10 lb 4 oz.
Green and yellow vegetables	3 lb 8 oz.	3 lb 4 oz	2 lb 8 oz	3 lb	12 lb 4 oz
Potatoes and sweet potatoes	2 lb 8 oz	1 lb 12 oz	1 lb 12 oz.	[illegible] lb 4 oz.	8 lb 4 oz
Other fruits and vegetables	3 lb 8 oz.	3 lb 4 oz	2 lb 8 oz.	2 lb 8 oz.	11 lb 12 oz.
Eggs	7	7	7	7	28
Meats	2 lb 12 oz	2 lb 8 oz.	1 lb 12 oz.	2 lb 4 oz.	9 lb 4 oz.
Dry legumes and nuts	2 oz	1 oz	2 oz	2 oz	7 oz
Cereals and flour	2 lb 8 oz	1 lb 12 oz.	2 lb	2 lb 12 oz	9 lb
Sweets	14 oz	12 oz	12 oz	14 oz.	3½ lb.
Fats	14 oz	10 oz	8 oz.	12 oz.	2¾ lb.

foods by days and planning the menus This might be called the quantitative approach While it is more accurate as to quantities, it involves considerable time, labor, and arithmetic on the part of a housewife It would be preferable if one were planning diets for an institution and perhaps may make somewhat more certain that low-cost diets will be adequate However, most Americans do not live at the low-cost level and would find it difficult to consume the amounts of bread, potatoes, and other starchy foods specified in the low-cost diets And even starting with definite quantities of all the different classes of food, the housewife still has a very considerable job to do in assembling these foods into suitable sized portions of dishes and meal combinations that will induce each of the family to eat the needed foods

For those who wish to plan in this way, we are including in the Appendix (pp 583 to 586) both the general plans for the number of servings in each food group weekly at low-cost and moderate-cost levels and the tables which give the allowances specified in each food group for every possible member of a family (from babies to grandmothers) at low, medium, and liberal cost levels [4]

As an example of how this plan works out, we will take a family of two sedentary adults and two children, eight and ten years of age From the marketing lists given in the Appendix, the quantities of each food group for each person per week are assembled in the table above, with totals for the family (the week's marketing list) in the final column We have elected to follow the moderate-cost food plan When the housewife has her totals for the week (e g., 24 qts milk, 10 lbs. citrus fruit and tomatoes, 28 eggs, 9¼ lbs of meat, etc.), it remains for her to distribute these *foods as to days, meals, and number of servings* (estimated from

[4] Both the general food plans and the detailed master food plans at three cost levels (weekly quantities of food for different members of the family) are taken from U S Depart Agric., Misc Pub No 662, "Helping Families Plan Food Budgets," rev 1955

Menus at Three Cost Levels

	Low	*Moderate*	*High*
Breakfast			
	Canned orange juice	½ grapefruit	½ cantaloupe
	Fried cornmeal mush, with corn sirup	Wheatena, with top milk and sugar	Puffed wheat, with cream
	Toast, enriched bread	Toast	Scrambled eggs and bacon
	Margarine	Margarine	Coffee cake
	Milk for children	Milk for children	Butter
	Coffee (adults)	Coffee (adults)	Milk for children
			Coffee (adults)
Luncheon			
	Potato salad, with canned peas	Bouillon	Cream of tomato soup
	Peanut butter sandwiches, enriched bread	Spinach ring, with creamed eggs	Grapefruit and avocado salad, French dressing
	Milk	Baking powder biscuits, with honey	Toasted cheese crackers
		Applesauce	Banana shortcake, whipped cream
		Milk	Milk for children
			Tea
Dinner			
	Casserole of rice, chopped meat, tomato, and green pepper	Veal loaf, with tomato sauce	Celery hearts and carrot sticks
	Carrots	Baked potato	Roast prime ribs of beef
	Shredded cabbage, raw, with vinagret dressing	Lima beans	Browned potatoes
	Prunes	Mixed green salad, French dressing	Broccoli
	Molasses cookies	Caramel custard	Endive salad, Roquefort cheese dressing
	Milk	Cookies	Ice cream, with chocolate sauce
		Milk for children	Cake
		Coffee (adults)	Milk (for children)
			Coffee (adults)

too many fatty foods (expensive items) to be the best for health, and this family might have to watch their waist lines, unless they kept to smaller portions of the wide variety of dishes Menus tell nothing, of course, as to the size of the servings consumed, but with fewer dishes in the low-cost meals, servings are usually larger. At each cost level, all the types of food considered essential to an adequate diet are well represented in the diet. They will be adequate, *provided* the homemaker sees to it that each member of the family (especially the children) receives and eats suitable sized portions of these essential foods (milk, meat and other protein foods, citrus fruit, green and yellow vegetables), appetite will usually control the intake of other foods so that the diet will be adequate for energy.

Another Way of Planning Adequate Diets at Different Cost Levels

Those who prefer may plan the diet starting the other way around, taking first the total quantities of the different food groups recommended to be included in the diet weekly (varying with different members of the family according to age, size, activity, etc.) and then distributing the

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pounds of food). In estimating the number of servings, the following figures may be of some help.

Food	Servings per pound	Food	Servings per pound
Cereals, uncooked	12	Potatoes and most cooked vegetables and fruit	3–4
Dried legumes	6–8	Raw vegetables	6–8
Meat, no bones	4		

QUESTIONS AND PROBLEMS

1. Name four factors that influence the cost of foods. Why were food prices so low in 1933 and so high in 1959? Name four factors, other than food prices, that affect the amount which a family will have to spend to be adequately fed.

2. Give the three principal ways in which economies in the food budget may be effected. Which are especially useful for families of low income, moderate income, and higher income? Why?

3. After consulting the diagrams and text in the preceding chapter (or other reference material), list the foods (or classes of foods) that are the cheapest sources of each of the following nutritive essentials: energy, protein, calcium, iron, vitamins A, B_1, and C. Could a nutritionally satisfactory diet for a low income family be made up exclusively from these foods, and if not, why not? When there is more money to spend for food, why is a more liberal expenditure for dairy products, fruits, and vegetables (and probably for meat and eggs) justifiable? Above what point is further expenditure for food not justifiable, and why?

4. Name as many ways as you can think of in which mineral or vitamin losses may occur in foods during storage or cooking. Outline the methods of storing, cooking, and serving foods best calculated to conserve their mineral and vitamin content. Why do we not eat all foods raw? What types of food have their taste, wholesomeness, or ease of digestion improved by proper cooking, and why?

5. Plan a day's menus for a young couple (both moderately active) with a 4 yr. old boy and 2 yr. old girl (1) at low cost, and (2) at moderate cost, stating size of portions eaten. Check the prices in a local market and make an approximate estimate of the cost of each of the diets planned.

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CHAPTER TWENTY-TWO

Food Fads and Fancies

A CHAPTER ON this subject deserves a place in a text on nutrition because anyone who has adequate training in scientific nutrition should be able to recognize false propaganda about certain foods or special systems of diet, even when these are portrayed in pseudo-scientific language. It is estimated that at least ten million persons in the United States are influenced by dietary fads and an estimate of the money spent for special health foods or vitamin products and to enrich the promoters of special systems of diet would be a fabulous sum

Aside from the money thus spent, such fads can do harm. Some people may react by becoming over-anxious about food The fear of certain foods or food combinations is instilled in them, so that they are not only prone to indigestion but readily fall prey to one food fad after another. In this way they may get one-sided diets, much less well balanced than if they had not developed food phobias Eating was meant to be enjoyed, all foods are good in their rightful place, and any food can be misused Thus the addict of food fads may not be as well nourished as one who exercises less anxious thought over what he eats, even though

the motive of the faddist has been to build health. And when special claims are made for either a "diet cult" or special foods in curing disease, credulous people who accept these claims and put faith in the food "cure-all" rather than see a doctor may be disillusioned by serious, sometimes even fatal, illness. It would seem that no one would believe that extra fat in the diet would cure rheumatism, or garlic juice banish high blood pressure, or a certain system of diet avert an operation for appendicitis, but they do.

Of course we have always had superstitions and false theories about food, for there have always been ignorant and credulous people in the world. Many current false ideas about food go back beyond memory to old superstitions. But as science developed in this country in the latter half of the nineteenth century, there appeared pioneers in the movement for better health through food. One was Rev. Sylvester Graham, who invented and championed the use of a flour made from the whole wheat kernel, and whose name still survives in the term Graham bread. Another was Fletcher, who taught that the *thorough* chewing of food was the magic for producing good digestion. Then, in the late 1800s and early 1900s, the two Kellogg brothers and C. W. Post developed and popularized their breakfast cereals, thus not only founding their personal wealth but revolutionizing the breakfast habits of America. Up to that time, a heavy breakfast had been the custom, often built around fried potatoes and meat. The lighter breakfast is probably better for us, especially since we use milk on cereal and usually have fruit for breakfast, now we have gone to the opposite extreme and have to urge people not to omit breakfast entirely or to take merely a cup of coffee.

Nutrition is a very young science, most of what we know having been discovered in the last fifty years. Nutritional knowledge has been quite well publicized and this has led people to become conscious that food,

Figure 141. Plight of those who believe the vendors of special health foods or systems of diet—troubled minds and loss of money.

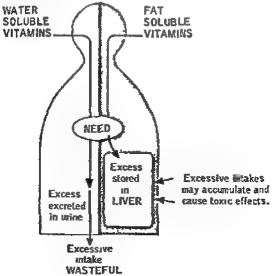
if rightly used, can build health One would hope that knowledge would enable people to distinguish fact from fiction in the field of foods, but unfortunately the average layman has not sufficient information for this and just enough to make him credulous when food quacks and faddists approach him with apparently plausible theories which promise much Fiction is usually more alluring than fact and, using a smattering of scientific terms which they themselves do not understand, the food propagandists can be very persuasive Thus we have the anomaly that, as people have become food conscious through the development of the science of nutrition, misrepresentations about food, food quackery, and diet cults have become big business

Some of these people may believe in their products, but even so they must realize that they are making a tremendous profit. A "reducing remedy" that consists chiefly of Epsom salts, a "high protein food supplement" that is cottonseed meal and yeast, a product that is finely ground alfalfa and a few other herbs sold as a "vitamin and mineral concentrate," cost but a small fraction of their sales price. Why do unrefined foods or those that would otherwise be waste products or cattle feed sell at "health stores" for higher prices than usual foods? In this class are unrefined (raw) sugar, wheat germ and bran, yogurt, and blackstrap molasses People have believed the propaganda that these foods have special health-giving properties, superior to the ordinary, wholesome foods they buy at the grocery store Yogurt is a good food but it costs more than whole fresh milk, and considerably more than dried skim milk, any one of them is an excellent source of calcium in the diet. The traces of minerals in brown sugar will not go far toward the total day's requirement, either refined or unrefined sugar must be supplemented by other foods that furnish protein, minerals, and vitamins. And the "vitamin and mineral concentrate" (alfalfa, etc.) which is supposed to be so much better because from "natural sources," will never carry on its label a statement of how much of the various vitamins and minerals it provides. Vagueness of statements on labels is the best way to steer clear of the law, since the Food and Drug Administration and the Federal Trade Commission are on the lookout for products that are falsely labeled as to contents, while the American Medical Association maintains a bureau to investigate products that make false claims either as to nutritional value or curative effects.

One sometimes suspects that the reason such products, designed to reinforce an already "good" diet with extra protein, minerals, and vitamins, flourish is the American tendency to overdo things If a certain amount of these nutrients make for health, several times as much should build even better health Thus the housewife who has already seen to it that her family gets a diet that comes up to the "recommended allowances" for all nutrients, still feels vaguely that they should be getting some vitamin supplement. Another serves a whole grain breakfast cereal

(such as wheatena or oatmeal) but insists that the family should put wheat germ on top of it Another serves plenty of milk but thinks the family should take calcium pills, just to make extra sure If the diet is already adequate, this is simply a waste of money since, in the case of most nutrients, the body can utilize only so much and no more. Excess of water-soluble vitamins is lost in the urine, fat-soluble vitamins can be stored but a liberal supply in the food daily will maintain body stores, and there is no added benefit from extra quantities (even danger from continuous use of high-potency preparations of vitamins A and D)

Commercial advertising of foods has become more circumspect in the past ten or fifteen years, but is still quick to pick up some partial fact or one not yet fully proven by scientific experiments, whenever there is a chance of using it to advantage The popularity of reducing diets is responsible for some false claims, e g , certain breads advocated for use in reducing diets (two slices before each meal to dull appetite) The average slice of commercial white bread furnishes about 63 calories, while those advertised for reducing range from about 55 to 69 calories. Obviously the calorie differences in different types of bread are negligible and one should cut down, rather than increase, the quantity of bread and butter in a reducing diet. Likewise, the advertising agencies for sugar and candy were quick to pick up and use the theory that appetite is controlled by a special center in the brain, which in turn is stimulated



by low blood sugar, hence the taking of sugar in some form between meals is advised to keep down appetite. This theory has failed to be proven yet. It takes many series of experiments, by several experimenters, to establish facts in science, and meantime misinformation may be widely publicized by written advertisements, and those sent over radio and television. Casting aspersions on a perfectly good food that is a competitor is not ethical advertising, e g., the television advertisement for butter which shows a housewife shamefacedly hiding a purchase of margarine, then deciding "my family deserves only the best." The same is true of advertising that urges one to give too large a place in the diet to certain foods, e.g , the "eat more meat" campaigns. All foods are "good" when taken in proper proportions and, since all are reduced before absorption into their common nutritive essentials, those in the same food group are often interchangeable in the diet

In recent years, one of the most popular and successful means of selling misinformation about foods has been the books written by laymen advocating certain systems of diet, and the same as spread by lecturers on "health" subjects. These people usually develop a following by reason of pleasing personalities and plausible mixing of proven and unproven facts, with their own deductions as to what makes for health Usually there are some special "health foods" to be sold after the lecture or by door-to-door salesmen later. They follow one of two lines, either to lure people with impossible promises of superabundant health or to scare them with the threat of imaginary ailments. In one such recent book, the author cited the case of a man who had died of heart disease and said his wife had only herself to blame since she had not seen to it that her husband got vitamin E It happens that doses of vitamin E did help animals with muscular dystrophy and associated heart disease, but unfortunately, when it was tried on human patients with these diseases, it proved to give little, if any, benefit Salesmen of preparations guaranteed to contain all the less well known vitamins and trace mineral elements also try to frighten with the idea that the diet may readily be deficient in one or more of these nutrients The facts are that many of them have not yet been shown to be essential for man and that they are carried in so many foods that there is little danger of any deficiency, if one eats a well balanced diet Iodine is the only mineral element which has thus far been proved to give rise to deficiency symptoms in human beings, because of eating foods grown in mineral-poor soils

Psychological factors are potent influences both in selling ideas about foods and diet and in determining the effects obtained by following these ideas. Fear and faith both have strong physiological effects. If one believes strongly that certain foods or combinations of foods will cause digestive distress, they are likely to cause such distress, but chiefly because of the psychic influences on the digestive organs On the other hand, the suggestion and belief that benefit will be derived is sufficiently

strong to be a force that makes for health, and credit may be given to the particular food cult followed When these are administered at a sanatorium, improvement of health may also be induced by baths, fresh air, and more exercise, as well as by the diet Patients who suffer from severe and chronic diseased conditions are not likely to obtain this type of relief. The pain-racked arthritic patient may have a pathetic "will to believe" but no amount of vegetable juices will cure him, when medical science does (we hope) find a cure for this disease, it will not be as simple as vegetable juices.

The federal agencies charged with protecting the public from exploitation as to foods and cures are making a determined effort to obtain evidence that will force at least the most flagrant offenders out of business Many are known and watched, if evidence is obtained, they can be prosecuted, with fines or even jail sentences, or their products may simply be confiscated If they know the government has sufficient evidence against them, they often voluntarily close up business, but frequently turn up elsewhere with a new firm name and a new product The best protection people could have against such exploitation is to be less credulous and to look at the claims made with more critical understanding. It is in the hope of fostering a better balanced judgment about food fads and fallacies that this chapter is written, and that we append a table of some common fallacies along with a parallel column in which we give the current scientific opinion on the subjects under the heading of "Truth" Neither column can, of course, be considered complete

We have assumed that the reader is familiar with the subject matter and the simple scientific terms that have been given in the preceding chapters of this book, as this simplifies the explanations a great deal The quaint wording which is to be noted in some of the "fallacies" comes from the original sources from which they were drawn and is representative of the way in which the older and more untutored ideas about food were, and still are, expressed To a person with modern scientific training, most of these ideas seem as quaint as the language in which they are couched

REFUTING ERRONEOUS IDEAS ABOUT FOOD

Fallacies	*Truths*
About certain foods: Tomatoes—clear the brain —are a tonic for the liver —make cancer Lemons }—aid digestion Oranges }—orange first thing in morning cures dyspepsia —cause "acid stomach" Raisins—needed by all for iron Figs, currants, and strawberries—are cooling and purifying Lettuce and cucumbers—are cooling foods Lettuce—is a soporific Onions—raw onion taken at bedtime a remedy for insomnia —onion soup good for weak digestion —will cure a cold —have marked effect on circulatory system Spinach—has direct effect on kidneys Celery—is a nerve tonic or food —will cure neuralgia —is of great use in rheumatism Fish—is a brain food —leads to increased reproductive activity Meat—needed to build muscle and red blood —produces mental and physical energy —poisons the system Egg white—injurious to kidneys Nuts—have special curative properties	There is little or no foundation for the belief in the special efficacy of special foods. Most of these myths are handed down from an age which believed in "black magic," concerning foods as well as other things They are akin to the legends that eating heart made one courageous, eating liver was good for liver complaints, etc. As has been brought out in the earlier chapters, the foods in the same food group are more or less interchangeable and the different tissues take up whatever nutritive elements they need from the blood stream, to which common reservoir of body-building materials all the foods have contributed when they were absorbed after digestion. Special foods do not go to build special tissues Fish does provide phosphorus-containing compounds and nervous tissue is rich in phosphorus, but meat, poultry, eggs, and milk are all rich in phosphorus also, and it requires a good many other elements besides phosphorus to build nervous tissues How celery, which contains little phosphorus, became associated with special efficacy for nerves is a mystery. Meat and raisins both contain iron, but so do many other foods. It is not necessary to eat muscle tissue to build muscle any more than we need to drink blood to renew our blood supply. As to certain foods being cooling or heating, good for this or the other disease, and stimulating to special organs or parts of the body, these legends are rather obviously nonsensical, especially when they contradict each other, as they often do. Acid fruits are supposed by some to be a cure for dyspepsia and by others to cause "acid stomach." Of course the stomach secretes a digestive fluid that contains the strong mineral acid, hydrochloric acid, which is so many times more strongly acid than lemons that there is no comparison. If we did not have an acid stomach, conditions would be very abnormal and unfavorable for digestion.

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
	Usually a small amount of the mild fruit acids, more or less, makes little difference in stomach acidity, although there are some abnormal conditions where it may exert an influence worth taking into account
Cheese—should not be eaten because too hard to digest Eggs—more digestible raw than cooked Bananas—are indigestible, especially for young children —are fattening —are good for reducing	Cheese is a highly nutritious but concentrated food If eaten in moderate amounts along with bland foods it is well digested Eggs are slightly more digestible cooked than raw Bananas, when thoroughly ripe (yellow flecked with brown), are well digested even by small children Their value in a reducing diet is due to the fact that they leave the stomach slowly, *so help prevent hunger* Whether fattening or reducing results depends on the total calorie value of all foods eaten Bananas and cream *plus* a good general diet will put weight on undernourished children, but one banana and a glass of skim milk make a convenient meal to take once or twice a day if reducing A medium-sized banana has about the same energy value (100 C) as a large orange
Milk—is fattening —is constipating —causes indigestion because of curd in stomach —helps cause cancer —is valuable in treatment of syphilis	One food is no more fattening than another except in so far as one has a higher fuel value, i e , is more concentrated as to its caloric content 100 calories (about 2 lb) of lettuce would be just as fattening as 100 calories (½ oz) of butter, if one could eat such a large bulk of lettuce Milk need not be constipating if enough fruits and vegetables are taken along with it If the curd formation in the stomach causes distress, heated milk, which forms a finer curd, may be used instead of raw milk In some cases, milk curd is irritating in the intestine and causes diarrhea, in persons allergic to it, milk may cause digestive disturbances, but most normal persons digest it without difficulty Milk has no relation, pro or con, to either syphilis or cancer
Honey / Brown sugar }—natural sugars and hence better for one than cane sugar	Although one may enjoy honey and brown or maple sugar for the trace of impurities which give them flavor, they are no better as body fuel than cane

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
Cane sugar } —is heating Beet sugar } —injures the chest —makes apoplexy	sugar. Dark brown sugar has a fair c tent of calcium and considerable iron no vitamins, honey carries some iron B vitamins, as well as small amount vitamin C. However, neither is usec large enough amounts to add apprecia to the mineral and vitamin content the diet.
Highly milled grains—should never be used Whole *grains—should always be used*	*Either* highly milled cereals or wh grains are good sources of energy protein but, *if the former are used, m*
Bran—should be taken by everyone	
Yeast—should be taken by everyone	taken in large amounts or by those wit sensitive intestine, is likely to do ha Some doctors feel that it is unsuitable anyone Yeast may also cause gas c tention and digestive distress in so people, and its high content of uric ac forming substances may be bad for otl types of individual. Little of the B-co *plex vitamins are absorbed from fr* (live) yeast, but if yeast cells have be killed (as in boiled or dried yeast) t *vitamins are more* available and the g forming properties are destroyed. Bo bran and yeast should be taken on
Prunes } —are "sure-cure" for constipation Figs }	tuce, celery, leafy vegetables, etc are e pecially useful in this respect but no sp cial food is indispensable or represents "*sure-cure*" *for constipation.*
Certain foods —Purify the blood —Build up resistance to bacteria —Combat disease by alkalinizing effect.	Claims of purifying the blood a chiefly made by "health food" quack This is a vague expression which carr no scientific meaning Normally the bloc carries little or no toxic substances ar the kidneys rid it of excess waste produc unaffected by food intakes

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
	Claims of remarkable powers of food in promoting immunity to bacteria are likewise to be distrusted A diet which supplies vitamins and minerals abundantly (or vitamin concentrates) will have a general effect in preventing susceptibility to infections but cannot promote immunity to specific bacteria The influence of "alkalinizing" in preventing or overcoming infections has probably been much exaggerated A well-balanced and varied diet is the best aid to health, and no special food (or medicine) with particular alkalinizing properties is needed
Vegetable juices —Possess greater potency in promoting health than the whole vegetables —Different ones have *specific effects* in building up along certain lines or assisting in cure of certain conditions.	Vegetables consist chiefly of water, fiber, some assimilable carbohydrate, mineral salts, and vitamins (or substances like carotene from which the body can make vitamin A) The pressed-out juice will contain the *water-soluble* carbohydrates, minerals, salts, and vitamins in dilute solution Most of the fiber will be left behind and discarded, as will also that portion of the carbohydrate, mineral salts, and vitamins which is not soluble in water The substances left behind are as much needed for promoting health (especially the fiber to prevent constipation) as are those obtained in the juices Hence, if one eats a *sufficient quantity* of the whole vegetables he will be just as well or better off from a nutritional standpoint than by taking the juices alone Fruit juices are not as wasteful products as vegetable juices, since the edible portion of fruits is comparatively low in fiber anyway, and most of the carbohydrate, mineral, and vitamin content is so freely soluble in water that it will be contained in the pressed-out juice Promoters of so-called "health foods" are chiefly responsible for the idea that vegetable juices have magic health-promoting qualities Different vegetables do not have specific effects in curing diseases
About food idiosyncrasies: Many people think that certain foods act as "poison" to them and cause illness	**Food Sensitization or Allergy.** A few people (less than 10 per cent probably) have real food idiosyncrasies, i e, they

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
even when taken in small amounts Most of these peculiar reactions to food are fancied, or are caused by the suggestion that distress will result from eating that food because it did on some previous occasion.	have at some time become sensitized to the *protein* in a certain food, so that whenever they get any of this food later a reaction results which may lead to the development of eczema, urticaria, wheals or itching in skin, asthma or shortness of breath, vomiting, or diarrhea This sensitization usually first develops through some irritation of the mucosa of the alimentary tract, so that it is weakened and lets some undigested protein pass through into the blood, where this acts as a foreign body and sensitizes the person to that food. It is always due to protein, and is more apt to occur in children than in adults. Children may outgrow a food sensitization, if the offending food is omitted from the diet for some time. In some cases a physician may locate what protein [illegible]
[illegible]	which are most often responsible for true [illegible]
[illegible]	and buckwheat) [illegible]
any other food.	cause body fat to be consumed, except in so far as a diet high in protein is known to raise basal metabolism slightly. Any food may be fattening, if taken in excess of the body needs. As to the supposedly fatal food com- [illegible]

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
The following are black-listed by different groups as being very bad combinations of foods: Lobster and ice cream Milk and cherries (or any other acid fruit) Acid fruits and starches Protein-rich foods with starches Meat with milk Two starches Two fruits Fruits with vegetables	likely to cause digestive distress, if eaten in any considerable amounts Lobster and ice cream come under this head and, when eaten in quantity or by those with feeble digestion, would be apt to cause trouble. However, they do not react to form any mysterious poison and persons of robust digestion may be able to eat them together in moderate amounts Two other foods hard to digest, say ham and cheese, would be equally apt to disagree if taken in large amounts, and spoiled seafoods alone may cause serious digestive trouble Large amounts of cherries taken with milk probably would cause distress, but there is no reason why persons of normal digestive abilities cannot take milk at the same meal with a moderate amount of acid fruit The gastric juice is far more strongly acid than any acid fruit Fruit acids are said to inhibit the digestion of starches because an alkaline medium is needed for the action of saliva Some physiologists claim that acid fruits in the mouth really cause the secretion of a more alkaline saliva Starch digestion is continued for some time in the stomach before its contents become acid, and is efficiently completed in the intestine, so any influence of acid fruits would be negligible. Concentrated protein foods and starches are supposed to be incompatible for the reason that protein foods are said to stimulate a greater flow of, or a more highly acid, gastric juice, which stops the digestion of starches by saliva, a process which goes on only in alkaline medium However, the presence of almost any food in the stomach (e g , carbohydrates alone) will stimulate the flow of acid gastric juice in sufficient amounts to halt the salivary digestion of starch in the stomach *after a moderate interval*, and we can depend on the efficient action of intestinal enzymes to digest any starch which escapes digestion in the mouth and stom-

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
	ach. It is of greater importance to chew starchy foods thoroughly than to watch carefully what type of food is eaten with them. Meat with milk is a food combination forbidden by certain religions but there are no physiological reasons against it, except that both are protein foods and taking too much of protein-rich foods may lead to neglect of other needed food groups The same is true of taking two foods rich in starch at one meal—there is no incompatibility between them, but smaller amounts of each should be taken or the diet is apt to be one-sided Two fruits, or fruits and vegetables together are not taboo in any sense, but rather to be recommended, as the more fruits and vegetables eaten the better. A few people find that fruit agrees with them better when taken alone rather than with meals, but it should not be omitted from the diet. *It is much more important to take a well balanced and varied diet than to worry about food combinations*
About the role of Nature: All foods should be eaten raw as this is natural state and cooking kills nutritive substances. No foods should be eaten raw, on account of the danger of infection with bacteria. Should eat only foods in season or native to the region you live as intended so by Nature Milk not intended by Nature to used as food after teeth are in	People who follow these schools of thought do well to spell Nature with a capital N, since they all imply that she has some special beneficent insight akin to that of the Deity Some foods are better eaten raw and other foods are better cooked, but there is no obligation on man to eat them in the natural state. Some [illegible] readily [illegible] esses [illegible] e ex- [illegible] iately digested and absorbed *If man had been content to eat only foods as provided by Nature, without importing food from other parts of the world or raising new foods when possible, he would have had a very restricted diet and civilization would not have developed as it has.* The [illegible] certainly [illegible]

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
	been developed as an especially well-balanced *food for maintaining life* and growth during infancy, means it must be a nearly perfect food for supplying body needs in later life also.
Vegetarian Diet: —Will lead to anemia, muscular weakness and lack of vigor —Talented or handsome people are rarely developed on such a diet, as a preponderance of cereal food deteriorates mind and body —Peoples on a vegetarian diet lack courage and stamina —Freedom from the poisons contained in meats leads to a higher state of health and to greater endurance	If the foods are wisely chosen, it is possible to have excellent physical development, vigor, and endurance on a vegetarian diet (e g , some of the Hindu sects) However, it is difficult to get all the elements needed by the body (especially calcium, iron, fat-soluble vitamins, and complete proteins) unless some foods of animal origin are included or a large amount of leafy vegetables is taken The human digestive tract is not well adapted to handling as large a bulk of leafy vegetables as would be needed if these foods alone had to make up the deficiencies of the cereal foods Most so-called vegetarians get around this difficulty by including milk, cheese, and eggs in the diet These foods are excellent to supply the complete proteins, vitamins, and mineral salts (especially calcium and iron) needed to supplement the strictly vegetarian diet Many of these lacto-ovo-vegetarians find they are better off without flesh foods
High meat diet: —Makes peoples fierce and warlike —Produces exceptional physical and mental energy and has a rejuvenating effect —Will necessarily lead to intestinal putrefaction, by which toxins are developed which will poison the whole system and result in disease —Is dangerous because of parasites or bacteria in meats	On the other hand, muscle meats are foods which satisfactorily supplement the protein deficiencies (but not the calcium and vitamin A deficiencies) of the cereals and legumes Meats also are good sources of iron and B-complex vitamins The idea that meats are a dangerous food is erroneous They do not contain toxins or dangerous kinds or quantities of bacteria, provided slaughter-house inspection is as good as it usually is, and the meat has been carefully handled and well refrigerated If thoroughly heated in cooking, any bacteria or parasites which might be present are killed anyway. Meats are easily digested and add to the appetizing qualities of the diet For most people there is no reason why they should not be used in moderate amounts Taking an *excess* of them may lead to intestinal

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
	putrefaction, to the formation of too much nitrogenous waste products (especially uric acid) in the body, and to a highly acid-forming and one-sided diet. Eating moderate amounts of meat does not necessarily lead to intestinal putrefaction any more than do moderate amounts of eggs, legumes, nuts, and other protein foods. There is little, if any, evidence that the *kind of food eaten directly influences* the disposition or the mental and moral traits of a people. The Eskimos, who eat a diet made up almost exclusively of animal foods, are a very good-natured and peaceable race, while certain of the Far Eastern peoples who subsist almost entirely on vegetable foods are by no means lacking in courage, stamina, and mental acumen. However, if the diet of a people is such as to be deficient in one or more of the nutritive essentials, that people will naturally degenerate physically, and will then show less initiative and lowered morale
About food and health habits: Fasting —should never eat when you have no appetite. —should not eat when sick as you feed the disease. —starve a fever and stuff a cold. —diseases will disappear if you starve long enough for the system to purify itself of toxins.	Appetite is no infallible guide as to what one should eat or how much It is often greatest in certain diseases which would be benefited by a short fast or limited food intake, whereas in illnesses such as fevers the sick person should be fed to prevent loss of weight and strength, since body tissues will be consumed for fuel if insufficient food is given One- to two-day fasts, with water, fruit juices, or green vegetables only, are often beneficial in intestinal putrefaction, overweight, and high blood pressure. Longer fasts may be very ill guided and should be taken only under a physician's advice Some sanitariums make a dangerous fad of long fasts, which may result in acidosis and even in death
Cravings —should eat whatever you have a craving for as it shows the system needs it, e.g., craving for acids means you need acids, craving for sweets means you need sugar, etc.	Special cravings are likewise no guide to body needs, and can be more safely ignored than indulged A craving usually results from lack of some food we have become accustomed to having. A child will have an abnormal desire for sweets if

Refuting Erroneous Ideas About Food—(Continued)

Fallacies	*Truths*
—dire results follow if special craving [redacted] not satisfied, especially during pregnancy.	he has been used to them, just as one acquires a craving for alcohol, tobacco, tea and coffee, etc The cravings of pregnancy are mostly fanciful and have no special significance
Omitting breakfast or lunch Sleeping immediately after meals Standing fifteen minutes after meals	None of these is a practice to be recommended Breakfast [redacted] needed after the twelve-hour fast through the night, and [redacted] stimulate evacuation of the colon and avoid constipation Lunch [redacted] needed to prevent overfatigue before evening, and the food is better handled by the body when fairly evenly divided into three meals If there is danger of over-eating, it is better to make all three meals somewhat lighter than to omit any one meal entirely Digestion is slowed down during sleep so it is best not to sleep soon after a meal, although lying down for a half hour after meals may favor digestion when it is weak Standing fifteen minutes has little influence of any kind
Drinking water with meals is bad for digestion Smoking aids digestion Chewing gum aids digestion	A moderate amount of water at the beginning or with meals helps increase the flow of digestive juices and hence aids rather than hinders digestion Smoking before or with meals inhibits hunger contractions of the stomach, but probably does not greatly influence the flow of digestive juices In persons predisposed to gastric ulcer, smoking when the stomach is empty may be harmful Chewing gum probably exerts no marked influence upon digestion Certainly the amount of pepsin gum contains is insignificant in comparison with the amount present in normal gastric juice
Mineral and vitamin concentrates: —Should be taken by most persons	[redacted] is possible to get a plentiful supply of all the needed minerals and vitamins in the diet, if foods are properly chosen and enough foods are eaten raw or in unrefined condition Vitamin concentrates are very useful for undernourished persons and for those whose diet must be limited because of digestive difficulties or diseased conditions They are best prescribed by a physician in the special cases where they are needed

QUESTIONS AND PROBLEMS

1. Explain why special foods would not exert an influence on one gan or set of organs in the body, why any two foods of closely related mposition have much the same effect on the nutrition of the body as a iole, and why foods in the same food group (of similar composition) ıy be used more or less interchangeably in the diet. Give examples ıt illustrate the application of each of these principles ın dietary ınning

2. Make a list of any prejudices that you may have against the eat- ; of certain foods or combinations of foods Are these prejudices war- ıted in the light of facts? Are you inclined to indulge in certain well ed foods or classes of food to the exclusion of other food groups that ; needed for proper nutrition? Have you any dietary fads or fancies?

3 Talk with several other persons and make a list of any super- tions about food, prejudices against or favor for certain foods, or ıctice of dietary fads, which you may find among these people. Which these may have some basis in fact and which are not based on reason? ve reasons for your conclusions.

4 Discuss the causes, whether physical, psychological, or emotional, ıy persons develop and persist in faulty food habits or take up with ɔd fads Make suggestions as to ways to induce such persons to alter ɔır food habits.

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CHAPTER TWENTY-THREE

Recent Trends in American Dietary Habits

A Glance at the Past

All nations start out with an economy based primarily on agriculture and, as the population and prosperity grow, gradually shift to a type of economy where agriculture is less prominent and industries that manufacture a wide range of products employ a larger share of the population. This entails a shift of population to cities and large towns, while fewer people live on farms or in towns small enough to permit of their having gardens, or of keeping chickens and a cow. The food supply is less locally produced, and often has to be assembled from many places and brought long distances. Many women work in factories or offices, so have little time for preparation of food or home canning. All this affects food habits. Certain foods become more expensive and are used in lesser amounts, whereas others are used chiefly as refined, canned, or otherwise preserved forms that keep well for storage and transportation. This change-over from a predominantly agricultural civilization to an

QUESTIONS AND PROBLEMS

1. Explain why special foods would not exert an influence on one organ or set of organs in the body, why any two foods of closely related composition have much the same effect on the nutrition of the body as a whole, and why foods in the same food group (of similar composition) may be used more or less interchangeably in the diet. Give examples that illustrate the application of each of these principles in dietary planning.

2 Make a list of any prejudices that you may have against the eating of certain foods or combinations of foods. Are these prejudices warranted in the light of facts? Are you inclined to indulge in certain well liked foods or classes of food to the exclusion of other food groups that are needed for proper nutrition? Have you any dietary fads or fancies?

3 Talk with several other persons and make a list of any superstitions about food, prejudices against or favor for certain foods, or practice of dietary fads, which you may find among these people. Which of these may have some basis in fact and which are not based on reason? Give reasons for your conclusions.

4 Discuss the causes, whether physical, psychological, or emotional, why persons develop and persist in faulty food habits or take up with food fads Make suggestions as to ways to induce such persons to alter their food habits

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Recent Improvements in American Diet, and How They Came About

The above mentioned signs of dietary deficiency were sufficiently obvious and widespread as to cause concern among many who were interested in public health. This was emphasized by the outbreak of pellagra in the southern United States, which forced us to recognize that large numbers of the population of this supposed "land of plenty" were getting so poor a diet as to develop a dietary deficiency disease. About the same time came World War I, with the necessity of more or less rationing the population as to fats, sugar, and wheat, in order that more of these non-perishable and concentrated foodstuffs might be sent to our allies in Europe. During these years also the science of nutrition was developing rapidly, in the thirty years between 1910 and 1940, most of the vitamins were discovered and isolated, and their physiological effects studied, as a result people became "vitamin conscious" for the first time. Then came the economic depression, which forced the study of inadequate diets and the planning of relief rations that would be adequate, even at low cost. Lastly, we were plunged into World War II and had to plan our food supply to afford excellent nutrition for the military forces and as good a diet as possible for the civilian population, and to conserve some food to export to starving peoples abroad. By the end of this period, we had become much more conscious of world food problems.

Probably *education* has been the foremost factor at work in improving our dietary habits. As the science of nutrition has made progress, this information has been popularized through many channels—instruction in schools, parent-teacher groups, Red Cross classes, classes for industrial workers or their wives, newspaper and magazine articles, and government "propaganda," especially during the war period. School lunch programs and the efforts of social workers and public health agencies have also assisted. There is increased interest in and appreciation of the importance of certain food groups for supplying some of the nutritive essentials that are most apt to be furnished in inadequate amounts in the American diet. Nutritionists have been putting increasing emphasis on the difference between diets that are just *adequate* and those that are *optimal* for promoting health, especially in respect to supplying plenty of high quality protein and all the needed mineral elements and vitamins. Many women have become ambitious to give their families the best possible diet, with a surplus of health-giving minerals and vitamins.

Second have come the *economic factors*. Higher levels of wages and income have helped to allow people to purchase more of certain groups of foods (milk, fruits, and vegetables), if they so desire. Increased demands for these foods have resulted in larger quantities being available, sometimes at lower cost than formerly. Over the past thirty years there has been a moderate but continuous trend to devote more land to pasturage and to keep more dairy cattle, manufacture of cheese, canned

industrial era took place in the United States during the course of the last century, and with increasing rapidity during the fifty years between 1880 and 1930 The changes which this brought about in our food habits are briefly summarized below

AGRICULTURAL ERA. In the agricultural era foods were locally produced, and farm animals were plentiful. Hence there was prominence in the diet of meats, locally milled whole grains, potatoes, fresh milk and cheeses, with plenty of fresh fruits and vegetables in season. During the winter, the fruits and vegetables were available only as root vegetables, home-canned fruits, jellies, and jams, and some in dried forms. The diet was probably adequate in most nutritional essentials, although there were less than optimal amounts of vitamin C in the winter months.

INDUSTRIAL ERA. With the invention (in 1879) of the roller mill process for making white or bolted flour, by which the germ, bran, and outer portions of the grain are removed, white or "patent" flour came into almost exclusive use for breads, and highly refined breakfast cereals increased in prominence Consumption of sugar increased over tenfold in the last century and nearly 40 per cent between 1910 and 1930 Other highly refined foods had increased use, e.g, polished rice, degerminated corn products, corn starch and corn sirup, vegetable oils, and fats such as lard and lard substitutes. All of these foods are good for body fuel but are almost totally lacking in mineral elements and vitamins, and in protein except for that in cereals Meats and eggs became more expensive but, being well liked, were consumed in much the same quantities so that they took a larger proportion of the food budget. Largely because of their expense, dairy products and fresh fruits and vegetables were bought in lesser amounts. An enormous canning industry developed, through whose activities surplus foods in season were preserved for transportation and for later marketing without spoilage Cold storage and drying processes also made foods available out of season and at cheaper prices. Some of these products have suffered little loss in nutritive qualities by preservation processes but others have lost in mineral and vitamin content, especially in vitamin C content. When over half of the food energy came to be furnished by foods that were low in or devoid of mineral elements and vitamins (highly milled cereals, sugar, and fats), any appreciable reduction of these nutritive essentials caused by aging, drying, or canning of such foods as fruits and vegetables was a serious matter. Reduction in average consumption of milk and cheese frequently led to serious calcium lack, only partially made up by the increasing popularity of ice cream The result of the change in dietary habits was a national dietary much too likely to be deficient in roughage, mineral elements (especially calcium and iron), and vitamins (especially vitamins A, B_1, and C) This was evidenced by dietary surveys and by prevalence of constipation, malnutrition, susceptibility to infections, and general lowered vitality.

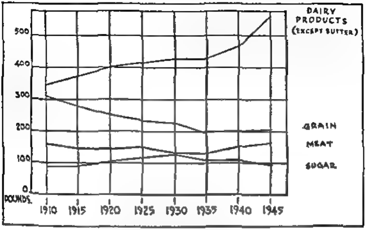


Figure 143 Graphs showing changes over 35 years in the annual consumption per person of four main classes of food including amounts used in manufactured products The upper curve shows consumption of milk and all milk products (other than butter), calculated in equivalent weight of fluid milk Consumption of dairy products (except butter) increased, the average daily consumption of milk increased from about 0 4 quart per person in 1910 to 0 7 quart in 1945 Consumption of grain products decreased about one-third in this period, while that of sugar and meats (including poultry and fish) remained about constant

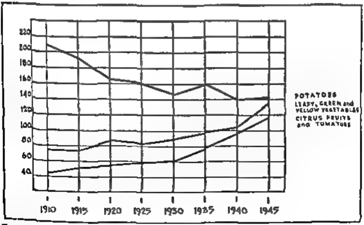


Figure 144
per person
decreased b
by 75 per c
period

milks, and ice cream has greatly increased. The campaign against pellagra in the South has centered about encouragement to make small gardens and keep a few hens or a cow At long last, the trend of population away from the large cities to suburban communities or country areas has again made it possible for many families to grow and enjoy the benefits of strictly *fresh* fruits and vegetables. In regard to fruits and vegetables, there has been almost a revolution in our supply; refrigeration and rapid transportation (by rail, truck, and airplane) have made it possible to deliver these foods from sunny, mild climates to places all over the nation without spoilage within a few days' time, so that in city markets there is a wide range of these foods to choose from at almost any season. One of the most marked developments has been that of the citrus fruit industry. Time was when an orange was a luxury, and this is still true in many lands. Now fresh citrus fruits are available at reasonable prices during most months of the year, and canned orange or grapefruit juices (or frozen concentrates) are rated as among the cheapest sources of vitamin C

Improvements by Shifts in Consumption

The gradual change in our food habits over the past twenty-five years or more is reflected in shifts in quantities of the various food groups consumed—shifts which mean nutritional improvement of the average American diet. The charts of apparent[1] per capita consumption of the major food groups show these trends clearly. Although there have been minor fluctuations from time to time, the quantity of meats, fats, sugar, and sweets consumed is about the same now as it was in 1910, but the consumption of *grain products* and *potatoes* has *decreased* since that date by one third In the same period the consumption of *eggs* has *increased* 32 per cent, that of *dairy products* (other than butter) about 50 per cent, that of leafy, *green and yellow vegetables* 75 per cent, and that of *citrus fruit and tomatoes* over 150 per cent. This means that we are now eating at least $1\frac{1}{2}$ times as much dairy products and $2\frac{1}{2}$ times as much citrus fruits and tomatoes as in 1910 Much of the increased production of and demand for these and other "protective foods" came about in the 15 year period from 1935 to 1950 For instance, the 1945 figures for apparent consumption were higher than the 1935–1939 average, in the case of dairy products by 25 per cent, leafy, green and yellow vegetables by 33 per cent, and citrus fruits and tomatoes by 40 per cent The 1955 government survey of food consumption[2] shows that there was little fur-

[1] The term "apparent consumption" is used because the figures do not indicate all of this food was actually eaten, some may have been lost through spoilage, waste, or in other ways Figures were obtained by adding stocks at beginning of year, total year's production and imports, subtracting ending stocks, material for non-food use and exports, then dividing the result by the number of the population The charts reproduced in Figs 143 and 144 (page 465) could not be continued beyond 1945, since comparable data are not available, but they indicate the trends during the period

recommended allowances are set at least 50 per cent above the minimum requirements, so that diets that furnish $\frac{2}{3}$ of the recommended allowance will probably be adequate In Fig 146, below, the student should notice that the picture is reversed, i e, the chart shows how many families had diets that *did not* come up to the NRC allowances, also how many furnished *less than* $\frac{2}{3}$ of some one or more essential nutrients (black bars). These latter are the critical ones, who are getting a diet that is inadequate in some respect It will be seen that, while 25–30 per cent still do not meet the optimum standards for calcium and vitamin C (ascorbic acid), only 10 per cent or less are in the critical "zone' of furnishing less than $\frac{2}{3}$ of the allowance, and the proportion of diets that furnish below required amounts of protein, iron, thiamine, riboflavin, and niacin is very small. This shows a gratifying improvement over the 1936 survey, when $\frac{1}{3}$ of the diets were called "poor," while now less than $\frac{1}{10}$ may be called "poor" when measured by the same standards

The authors of the survey attribute most of this improvement to higher average incomes (especially in the lower income groups), to general awareness of the importance of certain food groups, to the use of more meats, and to the enrichment of bread The greatest number of diets that did not measure up to the NRC recommended allowances were in the lower income group ($2,000 to $3,000) and the fewest were in the highest income group ($6,000 to $8,000) But it was noticeable that there was very little difference between the adequacy of the diets

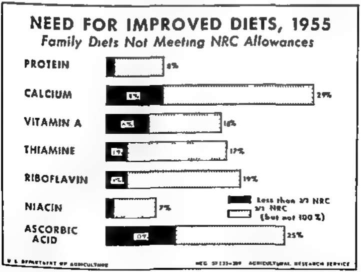
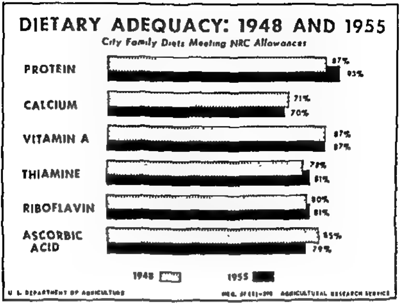


Figure 146 Only 10 per cent, or less, of the diets surveyed in 1955 were in the "danger zone" of furnishing less than $\frac{2}{3}$ of the standard allowances for various nutrients Protein and niacin are least likely to be provided in inadequate amounts, while ascorbic acid and calcium are the nutrients most often provided in less than optimal quantities



a fairly high level of dietary adequacy

ther improvement of the quality of average diets above the levels fo in 1948.

Probably this latest dietary survey is best used to measure how we have come toward our goal of providing an *adequate* diet for all an optimum diet for as many of our citizens as possible. When the qu tity of the different food groups purchased[3] per person per week is c pared with the similar figures for 1948, it is to be seen that the sumption of meat, fish, and poultry has increased, that of grain prod has slightly decreased, while that of milk, vegetables, and fruits rem about the same The consumption of green and yellow vegetables and citrus fruits also remains at about the same levels These facts expl why there was little difference in the proportion of diets that measu up to the National Research Council's recommended allowances in 1 and 1955 (as shown in Fig 145) It should be remembered that th

sample families were also varied as to income levels

as a substitute for one that has become quite expensive (butter). In addition, margarines are made from fats that are by-products, while the diversion of large amounts of milk to butter-making often means the waste of the valuable calcium-containing fluid portion of the milk (skim milk) for purposes of human food. Most of the restrictive laws on margarines have now been repealed and they are sold freely (at low prices) in the fortified and colored form. Yellow coloring matter is usually added to butter, as well as to margarines, during the manufacturing process. Usually some milk is churned into margarines to make their flavor and consistency approach that of butter. Almost all brands of margarine now have 15,000 I.U. of vitamin A per pound added, a vitamin A level that was determined to be the year-round average for butter, while some have vitamin D added.

Vitamin D milk is milk that has had its normal low content of vitamin D increased (usually by addition of a tasteless concentrate of that vitamin) up to the level that a quart of it daily will protect an infant or young child from rickets (400 I.U.). Milk was chosen as the best food to reinforce with vitamin D, because it also carries the calcium and phosphorus needed to help build strong bones and teeth, in conjunction with this vitamin. Evaporated and dried milks are also available that are reinforced with this vitamin. For young children who receive a quart of vitamin D milk daily, cod liver oil (or other concentrated forms of vitamin D) are not required.

Iodized salt is refined salt that has had small amounts of iodine salts added to replace those lost in the refining of natural sea salt. The effective use of iodized salt for the prevention of simple goiter in regions where the water, soil and foods grown on the soil are iodine-poor was described on pages 180–181.

The addition of mineral elements or vitamins to foods other than those enumerated above has not been considered necessary or advisable. Usually such foods are unduly expensive and the quantity of additional *minerals* and vitamins thus obtained is *insignificant*. Suitable amounts of natural foods are more effective in providing *all* essential nutritive factors in *proper proportions* for promoting health.

World Food Problems

We have had world food problems brought strongly to our attention by the suffering caused by lack of enough food or of proper food in many nations during and since World War II. In certain parts of the world there has never been enough food for everybody to be adequately nourished or to prevent many from going hungry. In populous Asian countries, every small piece of arable land must be intensively cultivated and all grains grown must go for human consumption, so there is none left for feeding livestock; in other countries, goats can graze on lands that would not support cattle. In many countries, primitive agricultural

used by moderate income families ($4,000 to $5,000) and those at higher income levels This emphasizes that the standard of living of the *middle class in this country is excellent* and much above that of any other country But one must remember that these are *average* figures, there are doubtless a good many individuals who, for one reason or another, are not taking adequate amounts of one or more nutrients, and doctors sometimes see cases where there has been a decided deficiency of some dietary essential The fact that such a high percentage of people have diets that provide the liberal amounts of nutrients recommended by the NRC, proves that *it is entirely possible to get an adequate or optimum diet* by the use of common foods, without vitamin and mineral supplements

Improvements by Enrichment or Fortification of Staple Foods

By 1939 various nutrition experts had come to believe that a few cheap, staple foods should be reinforced in nutritive value by addition of certain mineral elements and vitamins. The production of synthetic vitamins at reasonably low cost made such a program possible It was thought that low-income groups, whose diet was most likely to be deficient in these nutritive essentials, were the segment of the population *least likely to be reached by education as to proper food choices* and most likely to have to depend heavily on bread and grain foods as cheap sources of body fuel

Hence, in 1941, the government recommended and established standards for the *"enrichment" of white flour* and bread made from it, standards which were amended somewhat in 1943 Iron, thiamine, riboflavin, and niacin are added to approximate the level of these substances in whole wheat products, thus partially restoring nutritive factors that were removed in milling processes Although in most states enrichment of flour is still on a voluntary basis, the proportion of white flour and of bread that is enriched has steadily increased Most housewives, if they buy white bread and highly milled cereals, now look on the wrapper to see whether bread, flour, or cereals are of the enriched variety.

It has been estimated that the enrichment of bread and cereals has increased the amount of the important (and rather scarce) vitamin B_1 (thiamine) *in the American diet by about 15 per cent* and added appreciably to the intake of two other B vitamins and iron The nutritional benefits to individual consumers will vary widely Persons who eat only 2–4 slices of bread a day will get little extra vitamins and iron in enriched bread, but to those who eat large amounts of bread and/or cereals their enrichment may be an important item in improving nutrition It should be remembered that even enriched grain products do not possess all the nutritive factors found in whole grains.

The *"fortification" of margarines* by addition of vitamin A has served the useful purpose of making these cheaper fats nutritionally acceptable

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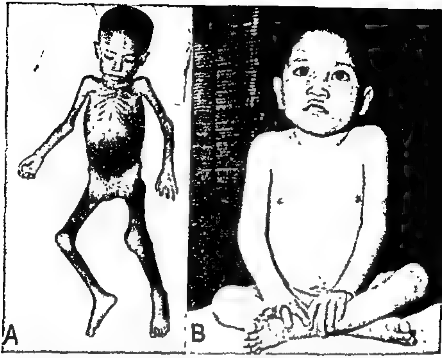

Figure 147 A Starvation is responsible for the pitiable condition of this three-year old girl found abandoned in the streets of Rangoon, Burma. B Same little girl after 3 months treatment at the Rangoon General Hospital She was adopted later by the doctor who took care of her. (Courtesy of the World Health Organization, United Nations)

methods are still in use and less than average yields are obtained in crops grown on the soil Malnutrition, deficiency diseases, and even starvation are not uncommon

The Food and Agricultural Organization of the United Nations has been studying world food problems of supply and demand, it also works through national nutrition organizations to appraise local conditions, to endeavor to raise the standards of living, and to promote better public health in the less fortunate countries. The United States government has also been trying to help both by sending food to nations where it was most needed and by sending agricultural and animal husbandry experts to show the people better farming methods—improvement of the soils, use of farm machinery or irrigation where suitable, introduction of better breeds of cattle and poultry and of improved strains of grains and other food-bearing plants The giving of a modern plow to a farmer who has always used an old-style wooden one in itself enables him to cultivate more land with less laborious methods Education of backward peoples in better methods of food production and in how to select an adequate diet from the foods available is a long-range objective that will require years of effort.

In addition to education and material help in enabling nations to produce more food for themselves, there must be world trade to share the surplus of the more productive nations with those that produce less food, many of whom need to exchange manufactured articles or raw materials for food This entails an economical use of food in the nations where it is chiefly produced For instance, in the United States it is common practice to "finish" cattle for market by excessive feeding of grain in feeding lots, this produces choice cuts that are "marbled" with fat and sell at higher prices, but it is wasteful of grain that could be more economically used for human food Much of the fat laid down in the animal is not eaten, and often the less tender cuts of meat are also wasted Cattle that put on weight on pasturage and small amounts of grain give better return in food value for the food eaten, and dairy cattle are even more economical converters of vegetable fodder into human food.

Figure 149 Two-year old African girl found to be suffering from both kwash-

When we think in terms of the world food supply, we must realize that there is just not enough animal protein available for everyone to get as high a quota as we have come to think desirable in this country. During the ten-year period from 1930 to 1940, our meat consumption averaged about 2½ lbs. per week for every man, woman, and child, and according to the 1955 family food survey it would now seem to have increased to about 4 lbs. weekly per person. The average per capita consumption of meat for the people of the world has been estimated as somewhat less than 1 pound per week, and of course many get far less than this amount We could conserve our fortunately plentiful supply of animal protein by doing any or all of the following things—use all edible parts of meat animals, including less tender cuts and glandular organs; eat more fish and poultry, use less meats and more of other animal protein foods such as milk, cheeses, and eggs, use legumes more plentifully, especially soybeans and peanuts which have high quality proteins. Such measures could make some meat available for export, and if less grain were used for animal feed more of it would be available for hungry people in other lands.

Of course we want our own people to be well fed and nutritionally fit We know that our high consumption in certain food groups is not evenly distributed, so that some diets do not measure up to the nutritional goals set by the recommended allowances of the Food and Nutrition Board When compared with the standards set by comparable boards in Great Britain and Canada, on which people get along at least fairly well, these nutritional goals look rather high and, compared with the type of diets common in many parts of the world, they look higher still. Our high standards of living do not make us loved by other less fortunate nations Yet there is nothing to prevent our maintaining a high nutritional level and still having food left to spare for other peoples Many Americans habitually overeat and would actually benefit by cutting down on their food intake, and we are almost unbelievably wasteful of food Perhaps if waste could really be eliminated, no other measures for saving food would be necessary in order to prevent the possible charge that we are selfish with respect to our plentiful supply of foods that are scarce in other parts of the world

QUESTIONS AND PROBLEMS

1. Which food groups were consumed plentifully by our ancestors in the agricultural era, and which were scarce? Was their diet usually satisfactory from a nutritional standpoint? If so, why, and if not, in what respects was it lacking? Discuss whether or not the diets of people living on farms are now nutritionally better than that of the average city dweller, and why

2 Name and discuss five changes in our food habits that were brought about by the industrial era, especially between 1880 and 1930 What effects did these changes in food consumption have on the health of the American people, and why? Were these effects equally noticeable in other parts of the world, and why?

3 What food groups are now consumed in larger amounts in the United States than formerly (say in 1910), which food groups do we now eat less of and of which group has our consumption remained about the same over the last 40 years? Discuss the influence on health which these shifts in food consumption would be expected to have

4 What shifts in our food consumption are recommended in order to conserve certain types of food for export to other nations that lack food? Will this have any adverse effect on the nutrition of people in the United States? What classes of foods need to be produced in greater quantities in order that peoples all over the world should have diets that are nutritionally adequate? How can this be accomplished? What one measure would do more than anything else to conserve food in America for use by peoples elsewhere?

5 What were the chief facts about the nutritional level of American diets brought out by the government survey of family diets in 1955?

What differences in adequacy of the average diet were shown by the survey of 1955, as contrasted with similar ones made in 1936 and 1948? Are American food habits improving and in what respects is there still room for improvement?

6. What staple foods have been enriched or fortified in recent years by the addition of minerals and vitamins and why was this done? How can the losses of nutritive essentials in foods in processing be lessened? How can these losses in cooking be minimized? What natural (unprocessed) foods could we well use more of in order to increase the mineral and vitamin content of the diet?

7 Make a list of American food habits that make for poorer nutrition and those that make for better nutrition.

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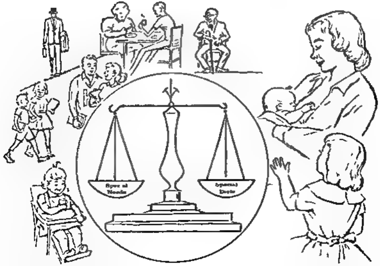
PART FOUR

Diet for Special Conditions



CHAPTER TWENTY-FOUR

Diet for Pregnant and Nursing Mothers

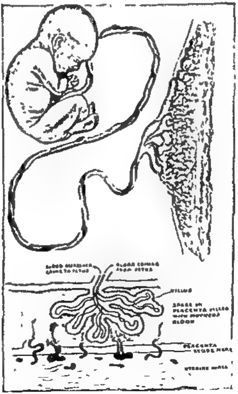
THESE ARE periods in which diet is of extra importance because the mother is nourishing the child through her own body, either in the uterus before birth or through the milk she secretes for the baby. Although both are entirely normal physiological processes, they do subject the body to special strain; the nutrients needed for the child must be furnished in her food or they may be drawn from the stores in her own tissues. A young woman who has good food habits and is well nourished when she becomes pregnant will have nothing to fear. She will need to alter her diet only by some increases in the foods she is accustomed to taking. Unfortunately, too many young women at present have either undereaten to keep slender or formed erratic food habits because they are absorbed in various activities. One who thus comes into the period of pregnancy in an undernourished condition, without the normal stores in her own body of those nutrients which can be stored, may be heading for trouble. Any border-line or latent deficiency may become apparent at this time. If her previous intake of iron and protein has been low, anemia or nutritional edema (bloating) may develop during pregnancy,

since the extra demands of the fetus may be enough to precipitate a real deficiency In others, whose calcium intake has been too low, the child may draw unduly on the calcium in the mother's bones and teeth, while in goitrous regions pregnancy is one of the times when latent iodine deficiency is likely to be manifested by enlargement of the thyroid gland. An undernourished mother may still be able to produce a healthy child, though there is evidence that a larger percentage of babies in poor condition are born to groups of mothers who were known to be in poor nutritive condition.

PREGNANCY

How the Child Is Nourished

There is no direct connection, either nervous or circulatory between the mother and the fetus, but interchange between the blood streams



of mother and child takes place through the placenta This is a vascular organ on the inner surface of the uterus, in which the blood from the mother and the fetus are brought closely together so that interchange of constituents from one to the other is possible Thus the fetal blood takes up all the food elements in the simple forms in which they are carried in the mother's blood and carries them to the fetus (through the umbilical cord) where they are built into the more complex substances needed to form the bones, muscles, and other tissues of the child This makes it evident that there can be no basis in fact for the myths regarding the special influences of certain kinds of food, or the thoughts or emotions of the mother, as exerting an influence on the growth and development of the child

Different Stages of Pregnancy

From the *first through the fourth months* of pregnancy, the need of materials for the growth of the fetus daily are so small as to be practically negligible The mother should eat just what any woman should who wishes to preserve or build up her health and vitality However, this is the period during which many women experience nausea or digestive disturbances, so that care should be taken to avoid overtaxing the digestive tract with too much food or foods difficult to digest Nausea in early pregnancy is due usually to adjustments in establishing connections between the fetal and maternal circulations, not primarily to misfunctioning of the digestive tract itself, and should soon disappear Food may be better tolerated in smaller meals at shorter intervals, a few crackers before rising may help (dry foods are not so apt to nauseate), also avoiding too much liquid with meals If vomiting is severe and prolonged, a state of semistarvation with resultant acidosis may develop, in such cases, carbohydrates should be given (sugar in fruit juice by mouth, if tolerated, or intravenous glucose solution in severe cases), pyridoxin (vitamin B_6) has been claimed to be of value for relief of vomiting but this is not too well established

By the beginning of the *second half of pregnancy* the appetite and digestive abilities of the mother should be normal, and it is from this time on that the National Research Council recommends increased allowances for almost all the essential nutrients These recommended allowances will be found in the table on page 452, contrasted with those of a young, moderately active, non-pregnant woman Some of the extra nutrients allowed are for the building of tissues in the child, some are intended for the protection of the mother's own tissues In the early part of pregnancy the fetus gains hardly more than 1 gram of weight per day, by the sixth month it gains about 10 gm daily, but about half of the total weight increase during gestation occurs in the last two

Table 22. Dietary Allowances in Pregnancy and Lactation

NRC Recommendations of 1958

Nutritive Factors	Non-pregnant Woman, 25 years, 58 kg	During 2nd half of Pregnancy	During Lactation
Calories	2300	Add 300	Add 1000
Protein	58 gm	Add 20 gm	Add 40 gm
Calcium	0 8 gm	1 5 gm	2 0 gm
Iron	12 mg	15 mg.	15 mg
Vitamin A	5000 I U	6000 I.U	8000 I U.
Thiamine	1 2 mg	1 3 mg	1 7 mg
Riboflavin	1 5 mg	2 0 mg	2 5 mg
Niacin (equiv)	17 mg	Add 3 mg	Add 2 mg
Ascorbic acid	70 mg	100 mg	150 mg
Vitamin D		400 I U	400 I U.

months. Therefore, during the two final months of pregnancy it is especially important that the diet should be unusually rich in all the nutritive factors needed for the growing child The extra calories needed should be taken in the form of foods which also provide high quality protein, mineral elements, and vitamins

The extra calorie allowance is not large (300 Cal. per day) and does not need to be, especially as women in the later months of pregnancy are often not very active physically Overeating as to calories will result in undue weight gain, while keeping caloric intake to too low a level will have little, if any, effect on the size and weight of the child but may produce a malnourished mother Most doctors believe a normal and desirable weight gain during the nine months of pregnancy to be about 20–25 pounds (including weight of the baby, enlarged uterus and its fluids), some suggest that the weight gain may be spaced at about 3, 10, and 10 pounds in each of the three successive 3-month periods.

Details as to Diet

The nutritive needs during pregnancy are best met by a simple, wholesome diet, the basis of which is *milk, eggs, meat, whole grains, fruits, and vegetables* In general, the more fruits and vegetables taken the better, since these foods not only help to ensure the surplus of *vitamins* and *mineral elements* which is so very advantageous, but make the diet *bulky* and *laxative* so that constipation may be prevented Whole-grain foods have the same effects as fruits and vegetables

Burke and Stuart[1] recommend that the diet during pregnancy be built around the following foods, both as to types and amounts of foods daily.

[1] Burke, B S, and Stuart, H C, "Nutritional Requirements during Pregnancy and Lactation," J A M A, 137, 119, 1948

Whole milk, 1 quart
Lean meat, 1 liberal serving (4 oz), liver desirable at least once a week
Eggs, at least 1
[illegible]
daily
Bread and cereals, at least 4 slices of whole grain or enriched bread daily, ½ c cooked whole grain cereal may be substituted for 1 slice bread
Butter or fortified margarine, 2 tablespoons
Vitamin D, some concentrated form in amount to furnish 400–800 I U

One may supplement these foods to furnish calories sufficient for individual energy needs and desired weight gain, either by taking more of some foods listed above or other foods of one's choice It should be remembered that the *energy needs vary* with weight and especially with degree of activity, so that the calorie allowance should be estimated individually, then increased in the second half of pregnancy by about 300 Cal. A moderately active, 58 kg woman (as listed in first column of Table 22 on p 482) who needs 2300 Cal normally should have 2600 Cal in the latter part of pregnancy But a sedentary woman whose ordinary daily energy need was only 1800 Cal would require only about 2100 Cal in late pregnancy On the other hand, a woman who begins pregnancy in an undernourished condition may need a more liberal calorie allowance in order to gain some weight

A woman who is overweight when she becomes pregnant will need to keep calories down in order to lose some weight (overweight is a hazard in pregnancy and childbirth), but calorie restriction should not be too severe (not below 1500–1800 Cal) and most of the weight reduction should be taken care of in the earlier months of pregnancy Foods containing sugar, starch, and fats should be the ones cut out, rather than protein, minerals and vitamin-bearing foods, and skim milk may be substituted for whole milk

Milk is probably the most indispensable food in the basic diet given above. A quart of it furnishes over three-fourths of the day's calcium allowance, as well as phosphorus, high quality protein, and valuable B vitamins, meat and eggs are good sources of all the latter named nutrients and are valuable for iron All of these foods, as well as cereals and fats, are lacking in vitamin C, so orange juice or other rich source of this vitamin is essential to meet the relatively high (100 mg) vitamin C allowance. Rich sources of vitamin A (deep green and yellow vegetables butter or fortified margarine) are needed, since the quart of milk will furnish only about one-fourth of the dietary allowance of this essential nutrient. Other foods listed for daily use obviously are valuable sources of mineral elements and vitamins.

The less elaborately cooked the food is the better, and some raw

foods should be taken daily (fruits and salads). If digestion is upset or there is difficulty in taking enough food, the regular meals may be reduced in size and extra nourishment given between meals in the form of easily digested foods, such as milk, eggnog, malted milk, cereal gruels, crackers, fruit, or fruit juice If preferred, much of the milk may be taken in dishes such as cream soups, custards, etc. Meals may easily be made to fit into the family schedule, if foods for the family are wisely chosen, i e, planned to be of high nutritive value and simply cooked.

The *habits of living* should be carefully looked to, since good nutrition is impossible, whatever the food supply, in the presence of such unfavorable factors as excitement, worry, overfatigue, irregular meal times, bolting of food, insufficient sleep, and constipation A moderate amount of exercise in the fresh air and sunlight is also essential Some rich source of *vitamin D* (in amount of 400 I.U.) is advised to promote good utilization of calcium and phosphorus, this may be obtained in a quart of vitamin D milk or taken in a concentrate capsule. Calcium pills are not needed if one gets a quart of milk daily and are definitely not a satisfactory substitute, since the milk provides so many valuable nutrients in addition to calcium In goitrous regions some extra source of iodine, as iodized salt, should be given.

Relation of Diet to Welfare of Mother and Child

The extra allowances of all the essential nutrients recommended for pregnancy (as per NRC allowances in Table 22, p 482) are a protection for both mother and child. They serve to provide abundance of building *materials for growth and development of the infant without* any need to draw on the stores of these substances in the mother's body, and they help to build reserves in the baby before birth of such nutrients as can be stored Enough energy must be supplied so that there will be no need to burn *protein* merely as fuel Obviously a goodly supply of all the essential amino acids will be required for fetal growth, so it is advisable

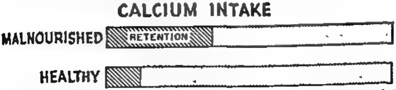


Figure 151 Some women enter into pregnancy with too low reserves of those ... Calcium is ... Ameri- ... alcium ... age of

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that at least half of the protein in the diet should be from foods of animal origin (milk, meats, eggs) A reasonably high protein intake is also thought to favor milk secretion in the period after birth of the infant. Leverton and McMillan[2] found that inclusion of extra meat daily in the diet during the latter half of pregnancy resulted in higher hemoglobin and red cell count in the mother's blood, greater freedom from edema, and superior ability to nurse their babies, than was found in a control group of women on ordinary diet or a group that received capsules containing some of the B vitamins furnished by meats

Extra *calcium* for the mother during pregnancy (and lactation) will go far toward ensuring teeth of good quality and well calcified bones in the child, the teeth of the child are formed and in large part calcified during the latter half of the period of prenatal life and the first few months after birth If the mother's diet is rich in *iron* during pregnancy, the child will be born with a liver well stored with iron, often a reserve sufficient to last through the months when it will be fed chiefly on milk, a food of low iron content The *fat-soluble vitamins* also can be stored in the liver and tissues of the fetus, provided the mother's diet furnishes them in abundance

The best evidence that the nutritive condition of the mother during pregnancy frequently influences not only her own health but the well being of her child comes from investigations at the medical schools of Toronto and Harvard Universities[3] In each case, pregnant women from low-income groups were studied during the later months of pregnancy,

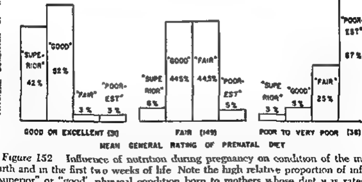

Figure 152 Influence of nutrition during pregnancy on condition of the infant at birth and in the first two weeks of life Note the high relative proportion of infants in "superior" or "good" physical condition born to mothers whose diet was rated as "good or excellent," and the relatively large numbers of babies in "fair" or "poorest" condition in the group of mothers whose diet was rated as "poor to very poor" (Courtesy of [illegible] S Burke and the Journal of Nutrition)

[2] Leverton, R M, and McMillan, T J, J A M A, 123, 134, 1946

[3] Ebbs, J H, Tisdall, F F, and Scott, W A, J Nutr, 22, 515, 1941, Burke, B S, *et al*, J Nutr, 26, 569, Am J Obst & Gynec, 46, 38, and J Pediatrics, 23, 506, all 1943

Figure 153 A case where the diet of the mother was sufficiently poor as unquestionably to affect the condition of her child This Indonesian woman evidently received in her diet barely enough vitamin A to prevent symptoms of deficiency in herself but not enough to protect the infant, which is suffering from the poor general condition, skin and eye symptoms (xerophthalmia) characteristic of severe deficiency of this vitamin One or two teaspoonfuls of cod liver oil daily for the mother during pregnancy, or perhaps even to the child immediately after birth, could have saved the sight of the baby (Courtesy of World Health Organization.)

and for some time after birth of the children. In the Toronto studies, the women in one group whose diets were poor received supplementary food, those in another group had self-chosen diets but were trained in food selection, those in the third group were left on poor diets as controls Those who received good diets had better health, both before and after delivery, fewer complications at delivery, also fewer miscarriages, stillbirths, or premature deliveries, than the mothers who were on poor diets during pregnancy At the Boston Lying-in Hospital, 216 women attending the prenatal clinic were classified according to whether their diets were considered good, fair, or poor No attempt was made to influence the diet, and records were kept of condition of mother and baby at and after delivery Mothers in the poorest diet group had more com-

plications and difficult types of delivery, while all of the stillborn babies and all but one of those who were premature or died soon after birth were born to mothers in this group Conversely, a higher proportion of babies whose condition was rated at birth as superior or good were born to mothers who had had good or excellent diets during pregnancy (see Fig 152). These studies offer evidence of a direct relationship between quality of the prenatal diet and welfare of both mother and child

Another series of observations tends to relate abnormalities or failures in pregnancy to poor diets Papers too numerous to cite present studies made in Europe either on very low income groups or following severe food restrictions during the war years They all seem to show that disasters in reproduction—premature births, stillborn infants, infants who were below normal weight and many of whom died soon after birth—were found in greater numbers among those who had very poor diets (either due to poverty or war) than was true when the diet was supplemented with minerals and vitamins or improved in other ways In this country, Dieckman[4] has shown that there is an increased incidence of abortion when mothers are on a low protein intake and, on the positive side, that the number of infants born in excellent condition increased steadily as the protein intake of the mothers was on a progressively higher level Darby and associates[5] at Vanderbilt University were unable to find a direct causative relationship between abnormalities in pregnancy and at birth of the infant with the nutrition of the mother, but add that this may be true if the nutritional level is sufficiently low They also state, "We do not wish to be interpreted as concluding that nutrition is unimportant in pregnancy"

LACTATION

Nutritive Requirements of Nursing Mother Higher than for Pregnant Woman

During lactation there is a very high need for energy, protein, minerals, and vitamins (1) to cover the amounts secreted in the milk for nourishment of the infant, (2) to cover the "cost" of secreting the milk, and (3) to protect the mother's own body As the result of extensive studies on successful nursing mothers, Shukers, Macy, et al[6] stated "Lactation increases the food demands approximately 60 per cent over and above those of pregnancy" The caloric value of the milk secreted accounts for one-third to one-half of the total energy intake, and the work of the mammary glands in secreting it is about one-tenth of the fuel value of the milk, in addition, there must be energy to provide for

[4] Dieckman, W J, et al, J Am Dietet Assoc, 27, 1046, 1951

[5] McGanity, Bridgforth, Martin, Newbill, and Darby, W J, J Am Dietet Assoc, 31, 582, 1955

[6] Shukers, Macy, et al, "Food Intake in Pregnancy, Lactation, and Reproductive Rest in the Human Mother," J Nutr, 4, 399, 1931

the mother's own activities. If insufficient energy is provided, either the mother will lose weight or milk secretion will gradually be suppressed

It also takes a very liberal intake of protein to sustain milk production, not all of which can be accounted for in the milk. Macy made intensive studies on three women who were unusually successful milk producers. Their daily caloric intake was between 3,800 and 4,600 calories and protein intake between 150 and 165 grams, or about 2 grams of protein per kilogram body weight (100 per cent above the level for normal adults) Naturally, the essential amino acids that are incorporated in milk proteins must be furnished liberally, it is interesting to note that one-half to three-fourths of the protein intake of these women was derived from animal sources, a great deal of it from milk

Since milk is so high in calcium and phosphorus, its secretion makes great demands for these mineral elements, the taking of 1½ quarts of milk daily is advised to help meet the high calcium needs, as well as for its other nutrients Nursing mothers are often found to be in negative calcium and phosphorus balance, this means a drain on the mother's body but does not affect milk secretion. The vitamin content of human milk, especially as to the water-soluble vitamins, is dependent on the vitamin intake of the mother Allowances recommended for calcium, and ascorbic acid are about double those for normal women, while those for iron, thiamine, riboflavin, and vitamin A are 25 to 50 per cent above the normal level Although little of the iron intake is passed on into the milk, the iron is needed to safeguard against anemia in the mother. Vitamin D (400 I U.) in supplementary form is needed to insure good utilization of the calcium and phosphorus The high allowances of various nutrients recommended during lactation may be seen by consulting the table on p 482

Diet for Nursing Mothers

Recommendations for the diet in the nursing period are almost identical with those given above for pregnancy, except that the need for almost all nutritive essentials is greater during lactation, especially as the infant grows and takes larger quantities of milk The *quality* of the diet required remains essentially the same—a diet high in calories and containing liberal amounts of milk, eggs, fruits, and vegetables to furnish the extra protein, mineral salts, and vitamins needed Probably some *extra quantities of the more concentrated fuel foods* (cereal products, potatoes, cream, and butter or margarine) will need to be added in order to furnish the large amount of energy that is required without too great bulk of foods Only the more simple, *easily digested* foods should be used, if the alimentary tract is not to be overburdened by the quantity of food taken

The average woman will require about 2800–3200 *calories*. In general, we may say that a woman of sedentary habits will need to consume

about as much food when nursing an infant as if she were doing hard muscular work, while a working woman will require approximately as many calories during this period as a man who is moderately active muscularly.

Milk is the best food both for promoting milk secretion and for protecting the mother's bones and teeth against any drain on calcium and phosphorus reserves to supply these elements in her milk At least 1 quart of milk should be taken daily, preferably 1½ quarts It is a good thing to take ***supplementary nourishment*** just before nursing the baby *in the middle of the morning and afternoon, and at bedtime Some milk* or cereal mixture is best, e g, hot milk, malted milk, buttermilk, cocoa, eggnog, graham crackers, oatmeal gruel with cream Milk soups, cream sauces, and custards should appear frequently in the menu, and in addition milk should be used as a beverage with meals, if possible It is essential to have a plentiful intake of ***fluids*** (1–2 qt from all sources) to provide the water in the milk secreted in addition to that needed by the mother, fruit juices and tomato juice are useful to give added fluids, as well as vitamins

While it is essential to have enough food to meet the increased requirements at this time, *overeating* will only upset digestion or result in an undesirable weight increase for the mother, without improving the quality of the milk or increasing the amount secreted. An excessive intake of vitamins will not increase the vitamin content of the milk above a certain level, although a low vitamin intake means vitamin-poor milk However, ***liberal intakes of vitamins*** are often helpful in stimulating milk production, for this reason, and also to promote better utilization of mineral elements, the taking of vitamins in concentrated forms is sometimes advised Orange juice, wheat germ on cereals, dried yeast tablets, and capsules of cod liver or halibut liver oil concentrates are all useful for this purpose The use of iodized salt is also sometimes recommended during this period

Advantages of Breast Feeding and Ways of Promoting Milk Flow

Human milk is specially adapted for providing all nutrients needed in the right proportions for the rate of growth normal for infants and in forms easily handled by the baby's digestive tract Cow's milk is designed for the calf, which should double its birth weight in about a third of the time that it takes an infant to do so, therefore, it has to be more concentrated in certain building materials and the more dilute human milk is better handled by a baby's sensitive digestive tract When cow's milk is diluted (one-half to one-third) for infant formulas, it may be difficult for the child to take a large enough volume to get the nourishment it needs In addition, human milk forms a much finer and more flocculent curd in the stomach than does raw cow's milk, though heat-treated cow's milk gives a curd that is more easily handled digestively

Lastly, cow's milk is liable to be contaminated with disease-producing bacteria and even nonpathogenic bacteria may multiply unduly during its handling and storage. *Even when pasteurized or boiled cow's milk is fed*, great care is needed to have all utensils sterilized and to store the bottles of formula in a cold place All of these dangers and difficulties are done away with when the baby is nursed by the mother; the milk is given direct from producer to consumer, and the child may take as much as desired with no chance of the "formula" not being readily *handled by its digestive tract.*

A far larger number of women could nurse their babies if they would follow a diet and habits of life such as favor the production of milk, both *during pregnancy* and in the months immediately following the child's birth "Successful nursing demands a quiet, contented life, in which food is intelligently chosen and exercise, fresh air, and mental diversion are provided."[7] Excitement, fatigue, constipation, and digestive disturbances all react unfavorably on milk production and must be guarded against.

There is no doubt that the character of the *diet* during pregnancy and lactation may affect lactation either favorably or adversely. The most important factors for stimulating a good flow of milk are liberal intake of *fuel foods*, plenty of high quality *proteins*, and an abundance of *vitamins*. Plenty of fluids should also be taken. A shortage of any of these essentials is likely to be reflected in decreased quantity of milk produced without affecting the quality of the milk so much. In case of a temporary shortage in the diet of protein, calcium, phosphorus, or fat-soluble vitamins, the amounts of these needed for the milk can be drawn from the reserve stores which have been built up in the mother's body, *provided* there has been a liberal supply of all these during pregnancy. A shortage of water-soluble vitamins, which cannot be stored to any appreciable extent, is apt to be reflected soon in milk low in these vitamins. It is interesting to note that normally human milk has about 2½ times more vitamin C than cow's milk, a fact which at least partially accounts for the high amounts of vitamin C recommended for lactation (150 mg daily) Women who have been undernourished during pregnancy enter the period of lactation with little reserves to meet its extra demands and in a condition in which milk secretion is apt to be scanty It should be emphasized that to insure good milk flow dietary conditions should be of the most favorable character throughout pregnancy, as well as after the birth of the child.

QUESTIONS AND PROBLEMS

1 Discuss the special problems and calorie needs of the different periods of pregnancy. Do the needs for protein, mineral elements, and vitamins differ in early and late pregnancy, and if so, how?

[7] Rose, M. S., "Feeding the Family," p 164, Macmillan, 4th ed., 1940.

2 By what selection of food groups could the higher calorie need of the last four months of pregnancy be satisfied and at the same time a diet rich in good quality protein, mineral elements and vitamins be provided? What food groups should be prominent in the diet during pregnancy?

3 What would be the dangers, if any, resulting from taking a diet during pregnancy that did not meet the requirement for energy, for protein, for calcium, for iron, for vitamin A, for vitamin D, for vitamin K, for vitamin B_1 (thiamine)?

4 Compare the allowances for each of the nutritive factors in late pregnancy with those for a woman who is nursing a baby (see Table 22, page 482) In what respects do the requirements in lactation differ from those in pregnancy, and why? Why are more calories, protein, calcium, phosphorus, and vitamins needed than are passed on to the baby in the mother's milk? Why do so many women become overweight when nursing a child? What factors in the diet, if taken in plentiful amounts, favor milk secretion? What nervous and environmental factors tend to suppress milk secretion?

5 Plan a day's meals for a woman in the last two months of pregnancy. Calculate the calories and protein in this diet, and compare with the allowances given in Table 22 (p 482) to see whether the diet is adequate in these respects Can you make any suggestions as to how it might be altered to provide more liberal intake of mineral elements and vitamins? Does the woman need some vitamin D supplement, and why?

6 Plan a day's diet for a nursing mother and calculate the amount of calcium and vitamin A supplied to see whether they are adequate If the diet needs to be improved in these respects, what changes would you suggest?

SUPPLEMENTARY READING

Books and Pamphlets

Burke, B S, and Stuart, H C, "Nutritional Requirements during Pregnancy and Lactation," J A M A, 137, 119, 1948, reprinted as Chap XV in A M A Handbook of Nutrition, 2nd ed, 1951

Children's Bureau, U S Dept Health, Education, and Welfare, "Prenatal Care," Pub No 4, 1949, "Infant Care," Pub No 8, 1955

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CHAPTER TWENTY-FIVE

Diet for Children and Teen-Agers

WHY DO WE need to treat the diets for children separately from those for adults? The nutritional factors necessary for the child are exactly the same as those for the adult—energy or body fuel, protein, mineral elements, and vitamins—and he will need to get them from much the same foods or classes of food It may seem repetitious to detail the foods that should make up the "core" of children's diets, since this list is very similar to the "basal or foundation diet" for adults But diet is vitally important for the growth, health, and happiness of children, and it requires special planning to see that their food needs are suitably met.

The nutritional needs of children differ from those of adults in three main respects

(1) Their *energy requirement* per unit of weight is higher than that of adults

(2) Their food should contain a higher proportion of *tissue-building*

Figure 154 Healthy, happy 2-year-old children, whose diet has provided plenty of all the materials needed for building sturdy bodies

materials (proteins and mineral elements) and of vitamins than that of adults

(3) Their diet should be made up of foods such as are suitable to the *digestive abilities* at any given age, and the scope of the foods that can be readily handled should increase as the child grows older.

Relatively High Nutritive Requirements of Children

Of course a small child does not need as much total energy as a grown man, but the amount in proportion to its size is greater (higher per unit of body weight). The *basal metabolism* (amount of energy used in the internal processes of the body) is greatest (per unit of weight) in *infancy* and gradually decreases throughout life, except for a brief rise at the time of *adolescence* Second, the child is usually much *more active* than the adult and uses a great deal of energy in work and play. Lastly, the child must have *extra energy to grow on*, or to store in the new tissues that are being built Infants have been found to store as much as 15 per cent of their fuel intake and 40 per cent of their protein intake during periods of rapid growth As the rate of growth decreases with age, the energy needed for new tissue is less and the basal metabolism is also less, but this is often offset by increased need for energy used in muscular tension and for physical activity Boys usually have a higher fuel requirement than girls, due to greater muscular tension and activity Energy requirement reaches its peak in the teen-age boy, when great muscular activity is combined with a high basal metabolism and a rapid rate of growth, the fuel needs of such boys are often greater than those of their fathers. A girl of 14 may also require more

energy (depending on her size, activity and rate of growth) than her mother (2200–2600 Cal.) The energy needs of children of different age groups is given in Table 23 on page 497, based on the *average* for the *middle* age of the group, with medium activity (NRC recommendations, 1958). This will need to be modified for individual children, according to size, activity, and rate of growth. Underweight or very active children will need a generous calorie allowance, overweight or inactive children should have less than the average fuel allowances.

The *protein allowances* for children are also higher per unit of body weight than those for adults The baby of one year needs 3.5 grams of protein per kilogram (2.2 lb.) body weight, the six-year-old about 2.5 gm., the adolescent boy or girl 1.5 gm., whereas the full grown adult needs only 1 gm. per kg. for maintenance For tissue building in growth, quality of protein is as important as quantity, for the essential amino acids will need to be plentifully supplied. The usual recommendation is that between 10 and 15 per cent of the calories should be taken in the form of protein and that from ½ to ⅔ of the protein supplied should be of animal origin (milk, meat, eggs) Milk has about 19 per cent of its calories in the form of protein, if a child gets a quart of milk daily, it

Figure 155 Good food helps to produce vivacity and charm, as well as good health (By Ewing Galloway, New York.)

Figure 156. The vigorous life of an adolescent boy increases his need for energy It should be provided through an increase in health-protective foods as well as in calories (Courtesy of DuPont Co, "Better Living" magazine.)

will be fairly certain to receive a good supply of protein of high quality and in easily digested form.

The allowances for *minimal elements and vitamins* are also disproportionally high in comparison with those of adults, when one considers the difference in size (see Table 23 on p 497). A four-year-old child who weighs 40 lb. is allowed more calcium than a man who weighs 154 lb, nearly as much iron, half the amount of vitamin A, and two-thirds as much vitamin C as the adult. Liberal calcium is of course needed for growing bones and for strengthening bones and teeth, iron for building new hemoglobin for red blood cells as the blood increases in volume Although we do not know just how the vitamins play a part in growth, we do know that all of them are required in considerable [illegible] to promote growth and for the building of healthy tissues. The

in greater proportion than for adults. Since the amounts of food that can be taken are limited and so are the child's digestive abilities, practically every food in the dietary must contribute its quota of protein, minerals, and vitamins if the high needs for these nutrients are to be met Milk is

Table 23. Recommended Daily Dietary Allowances for Children*

National Research Council, Revised 1958

	Calories	*Protein, gm*	*Calcium, gm*	*Iron, mg*	*Vit A, I U*	*Thiamine, mg*	*Riboflavin, mg*	*Niacin (equiv) mg*	*Vit C, mg*	*Vit D, I U*
Children up to 12 yrs										
Under 1 yr	110 per kg		6– 8	5–7	1500	4– 5	5– 8	6–7	30	400
1–3 yrs	1300	40	1 0	7	2000	0 7	1 0	8	35	400
4–6 yrs	1700	50	1 0	8	2500	0 9	1 3	11	50	400
7–9 yrs	2100	60	1 0	10	3500	1 1	1 5	14	60	400
10–12 yrs	2500	70	1 2	12	4500	1 3	1 8	17	75	400
Children over 12 yrs										
Girls, 13–15 yrs	2600	80	1 3	15	5000	1 3	2 0	17	80	400
16–20 yrs	2400	75	1 3	15	5000	1 2	1 9	16	80	400
Boys, 13–15 yrs	3100	85	1 4	15	5000	1 6	2 1	21	90	400
16–20 yrs	3600	100	1 4	15	5000	1 8	2 5	25	100	400

* These allowances are based on the needs for the middle year in each age group (as 2, 5, 8, 11 etc) and are for moderate activity and for average weight at the middle year of the age group

essential for calcium, milk, meat and eggs for protein, citrus fruits for vitamin C, green and yellow vegetables for vitamin A, etc Variety is not so important as getting in enough of all the needed nutrients in simple, easily digested foods that can be taken in the required amounts by a child

Digestive Abilities

The alimentary tract of very young *infants* is not equipped to digest *starches*, and this ability is developed gradually as small but slowly increasing amounts of thoroughly cooked cereals and potato are added to the diet during the first year Babies can digest the emulsified fat in milk (and later in egg yolk) but the total amount of fat they can handle is limited, so that butter or margarine is usually not given until the second year and then in limited amounts. Infants and young children seem to have less immunity to the presence of *bacteria* in the intestinal tract, and the mucous membrane lining their alimentary tract is also more *sensitive to irritating substances* than in later life Hence, we have to take pains to keep the food as free from bacteria as possible during infancy (boil the water, pasteurize the milk, keep milk chilled, etc), and we feed only *soft* foods during most of the first year, straining cereals, fruits and vegetables to get rid of the rough particles The change from puréed to finely chopped

Foods which are *difficult to masticate* (vegetables, meats, nuts, etc) should be given to young children in finely minced or ground form *Raw*

vegetables and most raw fruits have to be introduced with caution as the digestive tract becomes stronger and the teeth are well developed (usually during the second and third years).

New foods must always be *introduced gradually*, and in the event they cause difficulty should either be withdrawn entirely for the time being or given in reduced amount. It is always necessary to *guard against overcrowding the digestive tract* of young children Their food needs are so great in proportion to their size that their digestive tracts are always carrying about as heavy a load as they can handle. This condition of an alimentary tract which is working at close to its functional capacity holds true even in older children who are growing rapidly, and *is chiefly responsible for the frequency of digestive disturbances in children.* Children are especially likely to have digestive distress after *eating when overtired* or when *emotionally upset*, or as a result of *eating between meals*, or of *overeating* of some favorite food

Pickles and *preserves, rich salads* or *salad dressings, pastries, fat meats* and *gravies*, heavy *sweets, condiments*, and *stimulants* are *ruled out of the diet* during the earlier years both to *safeguard digestion* and to *avoid crowding out* the more important *foods which carry body-building materials* They also pervert the taste so that bland foods (milk, cereal, vegetables, etc) which are essential for growth are apt to be refused All of the above reasons apply to *candy* and sweetened drinks, only small amounts of some simple candy (hard ones are best) should be given to children, and then only at the end of a meal on special occasions The craving for sweets is a habit all too easily acquired

FEEDING NORMAL CHILDREN AND TEEN-AGERS

Gradation of Diet to Suit Age

The foundation of every child's diet should consist of milk and butter or fortified margarine, suitable cereals and bread, fruits and vegetables, meats, eggs, and simple, nutritious desserts and soups, other foods are unnecessary, and for young children they should either be omitted entirely or used only occasionally and in relatively small amounts. The problem of adapting the diet to suit the child's age and digestive capacities thus resolves itself into only a few phases, namely

(1) *Increasing the quantity* of some of the simple foods which formed the basis of the diet in earlier years, as the energy need grows
(2) *Changing the form* in which these foods are given, as the digestive tract [illegible] larger particles
(3) [illegible]
(4) [illegible] *easily digested*

The *age* at which certain alterations in the diet can and should be made *will vary with different children*, depending upon the general *sturdiness* and *activity*, rate of growth, and especially upon the condition

and *functioning of the alimentary tract* It must be understood that the suggestions given below are based on what has been found to work well for most normal children, but they are not iron-clad rules. Some children may be able to take certain foods earlier than the ages indicated here, delicate children or those with digestive abnormalities, on the other hand, will have to increase the scope and quantity of their food intake more slowly than robust children It is essential to make all changes in diet very gradually (at first small amounts at intervals of a few days) and to go back to the simpler diet temporarily whenever it seems advisable to lighten the child's digestive load (e.g, when a new food disagrees, or in case of illness) It should be emphasized that the simpler diets advised for younger children are adequate in respect to all of the necessary nutritive factors, and so will do just as well for an older child if a *larger quantity* is eaten.

As the child grows and develops, however, it is well to *increase the variety* of the diet and to *introduce new foods,* usually as soon as the child's digestive tract can handle them successfully The modern tendency is to introduce a considerable variety of foods into the diet even in the first year This is done partly because a milk diet needs to be supplemented as to a few nutrients (chiefly iron and vitamin C) and partly to begin training to like new foods at an early age The mother should not be apprehensive about introducing the child to new foods, nor force a child to take foods which at first it does not like If the food should disagree or the child refuse it, she should let the matter drop for a time but try again in a month or so Patient persistence and attempts to give the food in more attractive form or combined with well liked foods work far better in training children to like many foods than undue pressure in offering a food because it is "good for you" Too much "fussing" about what a child eats often leads to refusal of specific foods or to a "finicky" appetite, either from stubbornness or because the child has discovered it gets attention in this way A child should be allowed some latitude in its food likes, and if it takes some of the foods in each food group that is all that is essential for health. When children have been trained early to eat a wider range of foods, their menus can be fitted into the family dietary earlier than otherwise, and of course a liking for most commonly used foods is an advantage throughout life

Diet during Second Year[1]

Probably by the time the child is one year old it will be on a three-meal-a-day schedule, with or without a little between-meal food The

[1] We have omitted any discussion of the feeding of infants (under 1 year), because

vegetables and most raw fruits have to be introduced with caution as the digestive tract becomes stronger and the teeth are well developed (usually during the second and third years).

New foods must always be *introduced gradually*, and in the event they cause difficulty should either be withdrawn entirely for the time being or given in reduced amount. It is always necessary to *guard against overcrowding the digestive tract* of young children Their food needs are so great in proportion to their size that their digestive tracts are always carrying about as heavy a load as they can handle. This condition of an alimentary tract which is working at close to its functional capacity holds true even in older children who are growing rapidly, and is chiefly responsible for the frequency of digestive disturbances in children Children are especially likely to have digestive distress after *eating when overtired* or when *emotionally upset*, or as a result of *eating between meals*, or of *overeating* of some favorite food

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(1) ... which formed the basis

(2) ... the digestive tract ... and larger particles

(3)

(4) ... *less easily digested foods* not allowable for young children

The *age* at which certain alterations in the diet can and should be made *will vary with different children*, depending upon the general *sturdiness* and *activity, rate of growth*, and especially upon the condition

Sweets should be limited, but a wider range of desserts is allowable, e g, simple ice cream and sherbets, or a small amount of simple cookies or plain cake occasionally. Fats may be used more generously, cream soups and soups that contain vegetables, rice, barley, or noodles are useful dishes for variety (clear meat broths not advised as they are filling but carry no nourishment) Potatoes may be baked, boiled, mashed, or creamed, and macaroni dishes may be used occasionally in place of potato, dry cereals may also be used occasionally Salads may be used but without rich, highly seasoned dressings, a little mayonnaise or cheddar cheese may be used, along with chopped raw vegetables, in sandwiches If between-meal snacks are needed, fruit juice or milk with crackers or bread are the best foods to give

Seven to Twelve Years

The diet from 7 to 12 years includes the same foods which formed the basis of the diet during earlier years, but in increased amount and wider variety The choice of foods and forms in which they are taken is now nearly as varied as in the adult diet, but most of the foods in the children's diet should be carriers of either energy, protein, minerals, or vitamins in order to meet their proportionately high nutritional needs

The following foods or types of food should be included in the diet daily, 3 to 4 (measuring) cups of milk, 2–4 tbsp butter or fortified margarine (including that used in cooking), 2–3 servings cereal or breadstuffs (more if desired, but not to crowd out other foods), at least 2 servings of fruit (1 citrus or tomato) with raw fruits frequently if possible, at least 2 servings of vegetables (1 leafy, green, or yellow) with salad or raw vegetable frequently, 1 potato, meat at least on alternate days with more egg, cheese, or legume on meatless days, 1 egg daily if possible, desserts once or twice (fruits preferable if main part of meal is not well taken)

If essential foods are eaten, appetite may control the quantity of other foods Concentrated sweets should still be avoided, but plain cake and cookies, jelly, dried fruits and nuts, and a wide range of simple desserts may be used in moderate amounts

Thirteen to Sixteen Years

The period from 13 to 16 years covers chiefly the years of high school and of adolescence, when both boys and girls are stretching up and should be filling out by building muscular tissues In addition, the iron needs of the girls are increased by onset of menstruation The girls "get their growth" earlier, and their food needs are somewhat less after the age of 16, whereas the needs of the boys are highest between 16 and 20 years However, both have relatively high needs for fuel and protein during this period (2400–2600 Cal for girls, 3200–3800 Cal for boys; 75–80 gm protein for girls, 85–100 gm for boys), the need for extra

orange or tomato juice, cod liver oil, or some milk and crackers may be given between rather than with meals, if the baby seems hungry or eats its main feedings better thus, but between-meal feeding should not be allowed to interfere with appetite for meals. At the age of twelve months, the baby will have become accustomed to most, if not all, of the foods that should make up the diet in the second year—cereals, dry bread, cooked fruit and vegetables (finely chopped), egg, a few meats (minced), and simple desserts. It is only necessary to increase the quantity and variety in these foods, gradually shift from minced to finely cut foods and introduce a few new types of food.

Cereals (¼–½ c twice a day) should be of whole grain or enriched variety and thoroughly cooked, although some of the partially precooked ones do not require long cooking Some of the less easily digestible vegetables can be given, mashed or chopped, but these should be *mostly the green or yellow ones (3–6 tbsp. twice daily), plus potato* (best baked) once a day Cooked fruit (pulp only) may be given once or twice a day, with occasionally some raw fruit (banana, pear, peach, apple, etc), and orange or tomato juice daily A whole egg can now be given on alternate days (or daily) and finely chopped meat (best beef, lamb, chicken, or liver), 3 to 7 times a week (1–1½ oz serving). Bread should be increased from one to three pieces daily by the end of the year (hard toasted is best), and simple desserts (Jello, Junket, cereal puddings, and custard) may be given once a day.

Children begin to want less fluid milk as they have more solid food and are growing less rapidly, they should drink *at least* a pint of milk daily, and most of a second pint can usually be worked into meals by use on cereals, or in creamed vegetables, desserts, etc One to three teaspoonfuls of butter or fortified margarine may be spread on bread daily, and cottage or cream cheese on crackers occasionally, 2–3 tsp. cod liver oil (or other rich source of vitamin D) is a "must" up to 2 years of age (unless vitamin D milk is taken)

Three to Six Years

The diet from 3 to 6 years should include mainly the same foods as in the second year, in increased quantity, except for milk, a quart of which daily is ample throughout the growth period and which should not crowd out needed solid foods Raw fruits may be given in wider variety, almost any kind by 5 years of age, raw vegetables should be introduced gradually, at first in small amounts (chopped), later in larger pieces to chew. Three-year-olds can have most kinds of meat or fish (in moderate amount—roasted or broiled, cut in small pieces), including canned fish, and by six years of age a child should be able to cut its own meat, meat, fish, poultry, and glandular organs are nutritious foods but should not have so prominent a place in the diet as to destroy the liking for the blander cereal foods, vegetables, fruits, and milk.

One of the light, prepared cereals may tempt the girl, or she may have fruit (orange juice, banana and cream, etc.), with whole wheat toast and milk for breakfast. Fruit and salads are usually well liked and a substantial salad (but not one made with meat or fish mixed with mayonnaise) may form an acceptable main dish for lunch. Other choices are a meat or cheese sandwich, soup made with milk or legume, or a hot dish such as macaroni with cheese, there should be some hot food or beverage used in connection with lunch. If lunch is not fairly substantial, it is very difficult to get in all the needed foods in the other two meals.

Dinner may be much the same as for adults but should feature green and yellow vegetables, green salads, breadstuffs, and nourishing desserts, in addition to meat and potato, of course. A variety in breadstuffs may tempt the girl's appetite, such as muffins, cinnamon toast, or nut, date, or raisin bread. If vegetables are slighted, more fruits may be used, and dried apricots are especially useful to furnish iron and vitamin A. The best desserts are cereal puddings and those made with milk and eggs, ice cream and simple cakes are acceptable but pastries should be sparingly used.

Seventeen to Twenty Years

Although growth is usually slowed down after adolescence, it should continue for four or five years thereafter, both as to increase in height and muscular development. The high energy needs of boys, both in this and in the 13–16 year period, are usually associated with a good deal of muscular activity. At about this age, young people usually go to work or away from home to college. There may be considerable differences in their energy requirements, according to whether they are active or sedentary. A young girl student or stenographer may lead a sedentary life and, even though her caloric needs are less, may present a feeding problem because of blunted appetite, skimpy lunches away from home, or desire to keep thin or to economize. It must not be lost sight of that she needs the body-building foods and, as calories go down, the relative amounts of protein-, mineral-, and vitamin-bearing foods should go up. If circumstances prevent getting enough vitamins in foods, vitamin capsules, wheat germ, or other concentrated sources of vitamins may be needed.

If previous good eating habits have been established, they usually carry over into this period, for of course the same types of foods are needed to make up a "basal diet" that is adequate or better than adequate. However, some young people bring bad food habits from their homes, some want to exercise "freedom of choice" when they are on their own, while some feel it necessary to economize on food. If they have not already learned the reasons why certain types of food are considered essential to a well balanced diet, some guidance should be given them now. This is a period when young people should finish out their

Figure 157 A substantial, well balanced lunch in the school cafeteria is an *important contribution to the health of Junior High School students, as well as good* training in food habits (Courtesy of Farley Manning Associates, New York)

mineral elements and vitamins is also apparent from the recommended high allowances for these nutrients given in Table 23 (p 497)

The aim should be to give highly nutritious, concentrated foods and *those not likely to overburden the digestive tract* *This means that it is* best to stick to much the same types of food used in the diet earlier, selecting energy-bearing foods mostly from those that also contribute protein, *minerals, and vitamins Usually the boys offer less of a problem, as* their appetite is excellent and they will "go for" plain and hearty foods; girls of this age frequently have a finicky appetite, preferring sweets and highly *flavored foods, and if they develop a "phobia" about remaining* slender it is difficult to get them to take foods that they need Milk should still be the main beverage, although cocoa and cereal coffee with a base of hot *milk may be used Too large an amount of fluids may* either lead to distention of the stomach or spoil the appetite for the more concentrated foods that are so much needed to furnish energy, between meal *recourse to "cokes," candy, or soda-fountain beverages* should be discouraged, if they are really hungry between meals, fruit, crackers or cookies, and milk are better foods to take.

Getting the girls *to eat a fairly substantial breakfast and providing* a nourishing meal at school at noon are two of the chief difficulties

Sample Menus for Children at Various Ages

1–2 Years	3–6 Years	7–12 Years	13–20 Years
Breakfast Tomato juice Oatmeal with top milk Whole wheat toast Milk to drink, 1 c	**Breakfast** Ripe, raw pear Corn flakes with top milk Egg, soft boiled Whole wheat toast Milk to drink, 1 c	**Breakfast** Banana Wheatena with top milk Omelette—plain Toast Milk to drink	**Breakfast** Shredded wheat with raisin sauce (thin cream) Scrambled eggs Bacon Muffins Milk to drink
Mid-morning Orange juice, 4 oz			
Dinner Egg, soft poached Baked potato Spinach (chopped fine) Zwieback Milk to drink, 1 c Rice pudding (no raisins)	**Dinner** Liver and bacon Creamed potato Asparagus tips Bread Milk to drink, 1 c Frozen custard Plain, crisp cookies	**Lunch or Supper** Vegetable soup with rice Creamed celery on toast Bread Milk 1 c Stewed figs with cream	**Lunch** Cream of split pea soup Pineapple, cream cheese, and nut salad Whole wheat bread Chocolate blanc mange Plain cake
Mid-afternoon Milk, 1 c Graham crackers	**Mid-afternoon** 1 orange		
Supper Cream of wheat (enriched) with top milk Bread and butter Apple sauce	**Supper** Macaroni and cheese Squash Toast Milk, 1 c Stewed prunes	**Dinner** Lamb chop—broiled Mashed potato Carrots and peas Shredded raw cabbage salad Bread Milk, 1 c Apple tapioca pudding with thin custard sauce	**Dinner** Broiled fresh salmon Baked potato String beans Lettuce salad, French dressing Whole wheat bread Baked apple with cream Cocoa (weak)

the "supper" type of menu given above may be used as lunch at school, with the main meal above 6–6:30 P.M. with the family.

Children under 3 are *better not fed at the table with adults*, as the proper food for them should be restricted and the meal hours best suited to their general health are somewhat different. They rise early and should not be up long before feeding, the mid-day meal should be arranged to come just before or after the nap, and a very simple and early supper is essential to a good night's rest and to getting them to bed in season (not later than 7.30 P.M.). The age at which a child starts having most of his meals with the family depends a good deal on the meal schedule of the rest of the family. If the family meals are at regular and reasonable

Figure 158 Healthy young people ready for college With favorable diet and health habits they may make further growth and build health in college years (Courtesy DuPont Co, "Better Living" magazine)

physical development and consolidate their health before the strains of later life. Only understanding of the advantages that accrue will make them willing to see to it that they get the right kinds and amounts of food when it is sometimes difficult to do so away from home

Meal Plans

The types of meals suited for children of different ages are illustrated in the specimen menus given on page 505

Young children need a simple *mid-morning* or *mid-afternoon lunch*, in order to avoid hunger and fatigue, at least up to 3 years and better up to [illegible] or 7 years of age With younger children or those inclined to be undernourished, milk or fruit juice should be given for this lunch, supplemented with a small amount of bread or crisp crackers With older children who are well nourished, this lunch may better be confined to fruit juice or some fresh fruit in season, in order to encourage them to eat well at the regular meals When the child enters school (usually when about 5 or 6 years old), the mid-morning lunch has to be discontinued unless it is given at the school, and a simple afternoon lunch is better suited to the new schedule. As the child grows older (7–12 year group),

to swallow their food until it is well *chewed,* and not to *wash food down with fluids.* Sometimes a single one of these bad habits of eating will be responsible for digestive difficulties which will cause the child to be undernourished. Carefulness is needed to see that the child does not work or play too hard, so that he comes to meals too excited or too tired to eat *Overfatigue and strong emotions* retard digestion, so introduce *rest periods before meals,* if necessary, and do not *scold or punish* a child at mealtime Accustom the child to having food only sparingly seasoned with salt or sugar Give some *hard food* at each meal to encourage chewing and to exercise the teeth and gums, give *water* liberally between meals and moderately at mealtime, give only moderate amounts of *iced beverages or desserts* with meals and prohibit, or at least greatly restrict, access to the "soda fountain" between meals

No greater *favor* can be done for the child than to train it to realize which foods are *essential,* to cultivate a liking for a *wide range* of these foods in the early years, and, in general, to inculcate both by precept and practice an attitude toward food which will make for health and happiness in later years

Planning the Family Dietary around That of the Children

The menus given on page 505 are meant to suggest how the food plans for children may be varied at different ages, but not that the different age groups should have different meals Obviously the family menus should be planned to include both the children and adults. This can be done satisfactorily in only one way, i e , by using as the *foundation of the adults' diet the simple, easily digested foods* which should form the basis of the *children's meal* In the ordinary household, it means a prohibitive amount of labor to prepare entirely different diets for the children and adults. A few extra dishes which are forbidden to children may be served for the elders but the morale of the children will be much better if they are not tempted to ask for other foods by seeing them served at the table A child is very apt to feel abused at being refused certain dishes, or to resent being made to eat what its elders are exempt from eating, on the other hand, children are prone to imitate those they look up to, and frequently take the cue as to their likes and dislikes in foods from their parents' habits in this respect

This practice should not entail any great hardship on the parents, the foods which are best for children are those which are best for adults, and their own health will undoubtedly benefit by refraining from the less digestible foods and taking plenty of the mineral- and vitamin-bearing foods such as milk, fruits, and vegetables The meals suggested on page 505 as suitable for children over 3 years of age do not seem unattractive to adults or differ very much from what they might choose, except that the suppers are lighter than most adults prefer, while milk is the main beverage and tea or coffee is ruled out An example of a

hours, a slight shift of schedule may enable the child to eat some or most of its meals with the family, in homes where there are several young children they may well continue to eat together at a small table. If there are guests for dinner or the dinner hour is late, it is best to give the child's evening meal ahead of that of the family.

For younger children, the most *substantial meal* is best given in the *middle* of the day, as they sleep better after an early supper of simple, easily digested foods. During school years, the noon meal frequently has to be taken away from home, and under these circumstances some arrangement should be made for *school lunches* which will assure at least one hot dish at the mid-day meal, with a substantial hot meal at home at night. However, the food for the day should be fairly evenly distributed between the three meals, with no one meal unduly scanty or large

The years from 13 to 18 cover the period of junior high school and high school (with mid-day meal taken away from home), which is a period when the need for all the nutritive essentials is especially high The menus suggested on page 505 for this period are planned to give highly nutritious *fuel foods* without too much *bulk* At the same time an effort should be made to have "tasty" and *attractive* foods in the menu, including some of the sweets and salads which are usually well liked, as well as the fruits and vegetables that are essential. In order not to overtax the digestive tract, all foods should be easily digestible

The importance of *regularity of meal times* and of *not eating between meals* can scarcely be overemphasized Probably no other single factor is so important for health, unless it is the character of the food eaten. The stomach needs time to rest between meals, and habit is a strong factor in securing the best working of the alimentary tract, which will adjust itself to secreting its digestive fluids more freely when food is taken at regular intervals and not too close together. Greater care is usually exercised with young children, both as to proper times of feeding and to selection of the diet, but, as the child grows older and especially when it comes to the family table, vigilance is relaxed and numerous "exceptions" to the rules are allowed. Too little significance is attached to having the meals of the whole family on a regular schedule. If between-meal feeding is needed, as for young or undernourished children, it should be at a regular hour (not too near mealtime) and should consist of simple, nourishing foods that will leave the stomach before the next meal. Between-meal feeding does no good if it results in less food being taken at meal times

Training in Food Habits

Encouraging the *right habits of eating* and the *proper attitude toward food* is also an important part of a mother's task in training her children. Children must be watched and taught from the first not to eat *hurriedly* nor to *dawdle* at the table, not to take too *large mouthfuls*, not

to swallow their food until it is well *chewed*, and not to *wash food down with fluids* Sometimes a single one of these bad habits of eating will be responsible for digestive difficulties which will cause the child to be undernourished Carefulness is needed to see that the child does not work or play too hard, so that he comes to meals too excited or too tired to eat *Overfatigue and strong emotions* retard digestion, so introduce *rest periods before meals*, if necessary, and do not *scold or punish* a child at mealtime Accustom the child to having food only sparingly seasoned with salt or sugar. Give some *hard food* at each meal to encourage chewing and to exercise the teeth and gums, give *water* liberally between meals and moderately at mealtime, give only moderate amounts of *iced beverages or desserts* with meals and prohibit, or at least greatly restrict, access to the "soda fountain" between meals

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Planning the Family Dietary around That of the Children

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family menu which can be adapted to suit the needs of both adults and young children is given below.

Breakfast

Grapefruit juice (canned)
Dark farina with milk
Toast Margarine
Milk for children
Coffee for adults

Lunch

Creamed eggs on toast
String beans
Jellied fruit salad
Oatmeal cookies
Milk

Dinner

Baked shoulder of lamb
Baked sweet potato Green peas
Green salad
Bread Margarine
Apple Brown Betty
(baked)
Milk for children

This is a fairly economical day's menu that does not involve too much work for the mother of young children A child of 2 or 3 years may have the grapefruit juice slightly diluted (if desired), the string beans and meat (small portion) finely cut, the peas and sweet potato mashed, and the green salad omitted. The jellied fruit salad may be made with finely cut canned fruit and be served without salad dressing for the young children, it may be prepared beforehand and at a time convenient to the mother The oven-cooked dinner is likewise a labor-saver and gives a wholesome, satisfying meal for the adults and older children, the pudding is suitable for all ages if it is not too sweet or heavily seasoned, any other oven-cooked dessert suitable for children could be substituted if desired, or white potatoes used instead of sweet potatoes, since green vegetables are well represented in the meals. The green salad should have a simple dressing (lemon juice, or French or boiled dressing), and children over 3 years may be given young greens, finely cut or to nibble on. Another relatively inexpensive meat or a left-over meat dish might take the place of the baked lamb, and soft-cooked eggs or creamed fish substitute for the main luncheon dish The more substantial meal might be served at mid-day and the luncheon menu used as supper, if this arrangement is better suited to the children and fits into the living schedule of the adults.

It is essential to family harmony and ease in planning meals for the group that *all should be willing to eat some of almost any food offered* Although it is not advisable to force one to eat much of an unacceptable food at one time or to eat any food for which one has a strong dislike, provided other similar foods from the same group can be substituted, such aversions to specific foods cause a great deal of extra trouble, and the ability to eat a wide range of foods makes for a well-balanced diet, and hence for good nutrition Adults should be careful not to make disparaging remarks about certain foods before children If everyone is

accustomed to eat cheerfully at least a small amount of all the foods which come on the table, a better *esprit de corps* and a saner attitude toward food will prevail One will be surprised in such an atmosphere to see how food prejudices are gradually overcome and what it is possible to accomplish in learning to like many useful foods

HOW TO TELL IF NUTRITIONAL NEEDS OF CHILDREN ARE BEING MET

Every mother is anxious to have ***assurance*** that she is giving her child the ***right kinds*** and ***amount*** of food, yet few have the ability, time, or inclination to keep an exact record of what the child eats, calculate its calorie intake, and compare this with the estimated amount of fuel food which a child of that age should require. Fortunately such a careful checking of calorie intake is not necessary, unless the child is ill or persistently undernourished so that a special diet has to be planned for it

We have two criteria for judging when an *adult's* diet is well adjusted to balance his nutritional needs—namely, maintenance of a state of positive *health* and of *stationary weight* (see page 84) *Children* should not remain stationary in weight but should be making ***consistent gains in weight*** (and height) throughout the growth period, although not always at a constant rate for it is normal for growth to proceed more rapidly at certain periods than at others Infants should be weighed at least once a month, and older children at regular intervals Although the monthly gain may not be regular, the weight should not remain stationary more than two months, provided the child is being properly fed and there are no abnormal conditions to keep it from gaining

Weight Gains

At what rate should children be gaining weight (and height), if the food is furnishing plenty of vitamins, building materials, and calories for them to make the normal gains? Table 24 (p 510), compiled from a number of different sources and representing the *average* figures obtained from weighing a great many apparently normal American children, will help to answer this question

It will be noted that the *periods of most rapid growth* are (1) during the *first year*, after which there is a gradual decline of rate of growth through the second and third years, (2) between the ages of *eleven to fourteen for girls* and *fourteen to sixteen for boys* The rate of growth begins to be accelerated about the eighth year, reaches a maximum during the years of adolescence, which are slightly earlier for girls than for boys as noted above, and then gradually declines until growth ceases

It should be emphasized that, *if* a child is getting *enough calories, body-building materials* (proteins, mineral salts, etc), and *vitamins* in its food, it will grow at approximately normal rate ***unless something else is holding it back.*** When a child is not making satisfactory gains, one

Table 24. Average Weight Gains of Normal Children

Boys			G	
	Approximate average gain			Appro
Age, years	Per month, ounces	Per year, pounds	Age, years	Per month, ounces
0–1	16	11–13	0–1	16
1–2	7	[illegible]	1–2	7
2–3	6	5	2–3	[illegible]
3–8	6	Avg. about 4½	3–8	6
8–12	8		8–11	8
12–14	12	9	11–14	12
14–16	16	13	14–16	8
16–18	8	6	16–18	4

Figure 159. A difference of five years in age and of four po
... ll and weighs 33 pounds, his brother Ralph is 3 an

should first look carefully to see if there is not a deficiency in food intake with respect to some of the nutritive factors (italicized above) which are needed for growth. If an honest facing of facts can disclose no possible *deficiency in the food supply* and no *bad health habits* which make for poor nutrition (irregular meals, late bedtime, overfatigue, bolting food, etc.), then a physician should be consulted to see if he cannot locate the factor which is keeping the child from gaining. There is always a reason (more often several), which can be discovered by persistent search and the correction of which should leave the child free to gain.

Figure 160. These are [illegible]

[illegible] Research Service, USDA.)

It is probably true that, although the figures given in Table 24 (p. 510) represent the *average* gains made by supposedly normal children, *better* gains could be made and children could grow to a *larger size*, provided the very ***best kind of diet*** were furnished them and all conditions for nutrition made as favorable as possible. On the other hand, children of different types of body build normally do not show the same rate of gains in weight and height.[2] A child of tall build may gain more in height and less in weight than the average, whereas one of short, stocky build inclines to gain in weight rather than in height. If weight gains are at least moderate and consistently sustained, and the child is in good health, the mother should not worry too much because her child does not conform to the average pattern

General Nutritive Condition

It is essential to do more than watch for gains in weight and height in order to insure satisfactory nutrition in a child. As with the adult, no

Figure 161 . Marked difference in growth and general nutritive condition of ... 9 years and 7 months old, comes ... mal height ... fren reared ... ed growth ... urtesy Dr

[2] Maintaining the proper ratio of weight to height is more important than making certain weight gains at a given age This will be taken up more fully in Chap 28, on malnutrition, and tables will be found in the Appendix (pp 588–593) giving the average weight of boys and girls at different heights, along with variations in school age children with short, medium, or tall build (at bottom of tables, on page 591 and 593)

diet can be called satisfactory which does not lead to a state of positive *health* and abundant *vitality*.

We all know the type of child who eats gluttonously, especially of *sweets* and *starchy foods*, and is *overweight* for his years and height, yet who is *inactive* physically (and sometimes mentally as well) and is likely to have *flabby flesh*, and *poor bones* and *teeth*, or to be *anemic*. Such a child has been getting ***too much fuel*** and ***too little tissue-building materials*** (especially calcium and iron) ***and vitamins*** in his diet to build sound tissues and make for good health. The extra fuel caused him to gain in weight but was deposited as excess fat, which is a burden rather than an asset.

The ***reverse type of malnourished child*** is the *thin, nervous, overactive, overstimulated* type, who is *underweight* for his height, fatigues easily, and is irritable, tense, and liable to digestive difficulties. Such a child may go on growing in height on a food supply which is inadequate to meet his needs both for activity and for building new tissues. Either type of poorly nourished child may be *anemic* and especially *subject to infections*, when the diet has provided an insufficient amount of iron or vitamins.

Between these two types comes the ***well-nourished child***, the amount and selection of whose food has been such as to furnish *all* the elements

Figure 162. [illegible]

all show marked stunting of growth and other effects of poor nutrition. (Courtesy Dr Miguel A. Guzmán, Institute of Nutrition for Central America and Panama)

needed to build a *good-sized, well-proportioned body*, with *firm muscles, sound bones and teeth*, plenty of *red corpuscles* in the blood, a *digestive tract* which functions so smoothly that it is overlooked, high *resistance* to bacterial infections, a *stable nervous system*, and a *happy disposition*

A mother will do well to keep in mind the standard of attaining *abundant health* and vitality for her children when judging whether they are taking the *best possible* diet The task of training a child to consume the proper diet becomes more rewarding when she realizes that this is one of the chief factors in building health and happiness for the child, both in the present and for the future.

QUESTIONS AND PROBLEMS

1 Explain why the requirements of children for energy, protein, mineral elements, and vitamins are relatively higher per unit of body weight than those of adults. What factors determine their *total* requirements for these nutritive essentials, and are their total requirements necessarily higher than those of adults? At what period are their total requirements for all nutritive essentials higher than those of normal adults?

2 What are the chief criteria for telling whether a child, at any age, is properly nourished?

3 Outline the types of diet best suited for children and young people of 1–2 years, 3–6 years, 7–12 years, 13–16 years, and 17–20 years, including any vitamin supplements that are needed.

4 Make a day's menus for a 4-year-old child who will drink little milk

5. Make a day's menus for an adolescent girl who is disinclined to eat because she wants to keep slender, for an adolescent boy who is always hungry

6 Make a day's menus for a family of two adults and children who are 3, 7, and 12 years of age. Plan the meals to be moderate cost and with most of the foods suitable for all members of the family (with slight modifications).

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CHAPTER TWENTY-SIX

Diet after Forty

Dangers of Middle Age

The high mortality between the ages of 40 and 60, especially in the United States among men, would indicate either an increasing strain at this period as a result of the growing demands of business and social life, or a lessening ability of the organs to meet their functions—probably both Deaths in middle life are usually due to the giving out of various vital parts of the body, when subjected to strain Nervous collapse, high blood pressure, hardening of the arteries, apoplexy, heart failure, and kidney disease are some of the types of functional disease that are likely to set in at this time

To meet this period successfully certain *precautions* need to be observed Of course the best insurance against wearing out in middle life is taking an optimum diet and following good habits of hygiene from [illegible]

1 *Cut down on the amount of food eaten* sufficiently to combat the tendency to put on weight

2. Be *moderate* in the use of *fats* (especially animal fats), *meats and eggs, salt, and condiments,* take *plenty* of *water*

3. Get *plenty* of fresh air and exercise, but *avoid strenuous exertions* which overfatigue and place undue strain on the heart.[1]

4. Take more *recreation* and *rest*

5 Cultivate mental hygiene (courage, poise, self-control), *avoid nervous strain* (worry, irritation, excessive excitement, or exhausting emotions).

Each of the above recommendations for easing up in middle life would repay discussion, but we have space here only to point out their effect in *sparing the somewhat weakened organism* from undue strain Suggestions 1 and 2 are designed to *prevent overweight* (perhaps also help prevent hardening of arteries and high blood pressure), to lighten the work of the *alimentary tract, liver,* and *kidneys,* and to favor *excretion,* suggestion 3 guards against making too great demands on the *circulatory system,* whereas suggestions 3, 4, and 5 are all useful in providing rest for the *nervous system* and for the whole body.

Prevention of Senility

The bodily condition known as "old age" or senility, although it almost *invariably develops sooner or later, is not the inevitable result of* living a certain number of years, and may be long postponed by the right dietary régime and manner of living On the other hand, a poor diet or the wrong mode of living may bring on premature senility. Some people are "older" in body at 40 than others are at 60

Senility is not the necessary result of wear and tear, but rather of *improper use of the body* and of habitually taking a *diet* which does not *maintain the tissues at their highest degree of vitality. Those* who succeed in retaining their youthful vigor in the later years of life are usually not inactive people but, on the contrary, are those who are active mentally and moderately active physically. The most noticeable trait which they have in common is adherence to a *simple diet* and a *regular life, free from immoderation* in all respects.

Modern nutritionists stress the possibility not only of increasing the number of years lived but of lengthening the productive period known as the "prime of life." The experiments of Sherman and his co-workers[2]

[1] Track sports, baseball, football, boxing, and competitive rowing or golf should be ruled out Walking, swimming, hunting and fishing, mild rowing or golf, bowling on grass, billiards and pool are forms of exercise suited to the later years of life Tennis, badminton, etc. are games that some persons keep up well into middle age but usually they play a more leisurely game than young people Keeping up exercise consistently and in moderation is the important thing

[2] Sherman, H C, *et al*, "Effect of Increasing the Calcium Intake," J. Nutr, 10, 363, 1935, "Nutritional Well-Being and Length of Life as Influenced by Different Enrichments of an Already Adequate Diet," J Nutr, 14, 609, 1937, "Responses to Different Levels of Nutrition Intake of Riboflavin," Proc. Nat. Acad Sci, 25, 420, 1939, "Vitamin A in Relation to Aging and to Length of Life," Proc Nat Acad Sci, 31, 107, 1945.

in feeding rats through the whole life span, and even through successive generations, on diets that were "adequate" or that were "optimum" as to certain nutritive factors are most suggestive. Those on the diet considered adequate appeared healthy and lived a normal length of life, but rats that received much higher levels of calcium, vitamin A, or riboflavin lived considerably longer and retained greater vitality almost until their death—the symptoms of old age were postponed. Riboflavin (vitamin B_2) has a striking influence in preventing signs of senility. If a young rat is deprived of this vitamin for several months it looks and acts aged, but if then given liberal amounts of riboflavin, it becomes supple, healthy, and young looking in a short time. We know less as yet about what are "optimum" amounts of the other nutritive factors, but it is generally agreed that much could be done to avert senility by proper diet. Mackay and Maynard found that rats which matured more slowly, because they received a lower caloric intake, lived longer than those that were liberally fed. Work of Elvehjem and co-workers[3] tends to confirm the theory that restriction of calories may lead to longer life span, at least in rats.

Figure 163. This retired man seems to have the prospect of happy years ahead. Proper diet and his hobby of gardening help keep him in good health. (DuPont, "Better Living" magazine.)

[3] Riesen, W. H., Herbst, E. J., Walliker, C., and Elvehjem, C. A., Am. J. Physiol., 148, 614, 1947.

We may sum up the advice on how to prevent the development of senility and prolong the active period of life, as follows:

Favorable Factors	*Unfavorable Factors*
1 Diet of simple, easily digested foods (a) which supplies sufficient calories and protein (b) which provides plentiful amounts of all essential amino acids *mineral elements* vitamins	1 Diet (a) which supplies an insufficient amount of any of the necessary nutritive factors (b) which involves a "luxury consumption" of total food, of animal fats or protein-rich foods, of rich foods, condiments, or sweets
2 Simple, regular life	2 Irregular life, with improper proportion between work, recreation, and rest.
3 Avoidance of unfavorable factors	3 Excesses which place undue strain on weakened organs or tissues
	4 Unfavorable mental or emotional conditions
	5 Constipation
	6 Overweight.

Decreased Body Needs

From the discussion in the preceding section as to the dangers of lowered vitality from too-low intake of nutritive essentials and the benefits that may accrue from high intake of certain minerals and vitamins in postponing senility and lengthening life, it should be evident that the idea of a sparse and abstemious diet for later life has gone out of style, and for good reasons. The same nutritive essentials (fuel, protein, mineral salts, and vitamins) are required in adequate quantities to nourish the body "from the cradle to the grave," and an insufficiency of any of them will do harm at any age

However, it is true that at least some nutritive factors are needed in smaller quantities in the latter part of life (especially after 70) than in the more active adult years There is no further need of tissue-building materials for growth, and the amount of these substances needed for tissue maintenance or repair may be less The need for fuel foods is reduced slightly in later years and it is generally held that the protein intake may well be reduced by about the same amount as the caloric intake Too little protein may be as bad as or worse than too much, and nothing said here should be taken to minimize the need for a certain amount of high quality protein to provide for tissue rebuilding, which goes on to some extent throughout life The principal curtailment should be in the intake of foods that supply only or chiefly calories.

The *calorie requirement* is materially *reduced* for two reasons—

(1) less energy is used in *muscular activity*, and
(2) the *basal metabolism* is lowered

The inner fires of metabolism actually burn more slowly in old age. It is estimated that the energy used by the body processes when at rest (basal

metabolism) is about 10 per cent less than formerly between 60 and 70, 20 per cent less from 70 to 90, and about 25 per cent less after 90 years of age Thus a man of average weight and in middle life would require about 1840 Cal per day for maintenance when in bed, the requirements of the same man, without any muscular activity, for maintenance alone at 60 to 70 years would be about 1650 Cal, and at 70 to 80 years, 1475 Cal In earlier life the muscular activity might be sufficient to raise the energy requirement 500 to 2000 calories, i e, to somewhere between 2300 and 4000 calories, depending on the amount of muscular work done, few men in their seventies do enough muscular work to raise their total energy requirement to more than 2000 calories Small, aged women may have surprisingly low calorie needs

Hence, it will be apparent that the *total amount of food,* especially foods of high fuel value, should be *somewhat curtailed after* reaching 60 years (slightly so even at 40 to 60 years of age), and *considerably reduced after* 70 A keen appetite, a fondness for fatty or starchy foods and sweets, the continuance of eating habits acquired in the more active years, or the increased money spent for food in the more prosperous years of late middle life, may readily result in the consumption by an elderly person of more fuel foods than are required for his diminished body needs

The caloric reduction should be accomplished chiefly by cutting down on foods that have high fuel value but contribute little besides energy (sweets, highly milled cereals, and fats), a high proportion of the calories taken should come from foods that are carriers of high-quality protein, mineral elements, and vitamins Otherwise the restriction of calories will mean restriction of protein, minerals, and vitamins that may do harm The "tea and toast" diet of little old ladies is distinctly not to be recommended Old people may easily become malnourished by taking too little food or a diet lacking in essential nutritive factors Appetite, gastric acidity, and perhaps absorptive powers and storage of vitamins and minerals may begin to fail with age The brittle bones of many old persons are evidence that not enough calcium has been available either for normal upkeep of bones or to replace unusual losses that may come with aging Thus everything points to the fact that the diet should be restricted as to little else but calories, and it may need more than ever to be high in some or most of the other nutritive factors

Decreased Functional Abilities

In the later years of life the *ability* of the body *to handle an excess* of food is *diminished.* First, the *loss of teeth* frequently results in inability to masticate hard or coarse foods Inadequately chewed foods may place an added strain on digestion, or the omission of all coarse foods from the diet may lead to constipation The movements of the alimentary tract and the secretion of digestive juices are slowed down,

We may sum up the advice on how to prevent the development of senility and prolong the active period of life, as follows.

Favorable Factors	Unfavorable Factors
1 Diet of simple, easily digested foods (a) which supplies sufficient calories and protein (b) which provides plentiful amounts of all essential *amino acids* mineral elements vitamins	1 Diet (a) which supplies an insufficient amount of any of the necessary nutritive factors (b) which involves a "luxury consumption" of total food, of animal fats or protein-rich foods, of rich foods, condiments, or sweets
2 Simple, regular life	2 Irregular life, with improper proportion between work, recreation, and rest
3 Avoidance of unfavorable factors	3 Excesses which place undue strain on weakened organs or tissues
	4 Unfavorable mental or emotional conditions
	5 Constipation
	6 Overweight

Decreased Body Needs

From the discussion in the preceding section as to the dangers of lowered vitality from too-low intake of nutritive essentials and the benefits that may accrue from high intake of certain minerals and vitamins in postponing senility and lengthening life, it should be evident that the idea of a sparse and abstemious diet for later life has gone out of style, and for good reasons The same nutritive essentials (fuel, protein, mineral salts, and vitamins) are required in adequate quantities to nourish the body "from the cradle to the grave," and an insufficiency of any of them will do harm at any age.

However, it is true that at least some nutritive factors are needed in smaller quantities *in the latter part of life (especially after 70) than* in the more active adult years. There is no further need of tissue-building materials for growth, and the amount of these substances needed for tissue maintenance or repair may be less The need for fuel foods is *reduced slightly in later years and it is generally held that the protein* intake may well be reduced by about the same amount as the caloric intake. Too little protein may be as bad as or worse than too much, and nothing said here should be taken to minimize the need for a certain amount of high quality protein to provide for tissue rebuilding, which goes on to some extent throughout life The principal curtailment should be in the intake of foods that supply only or chiefly calories

The *calorie requirement* is materially *reduced* for two reasons—

(1) *less energy is used in muscular activity,* and

(2) the *basal metabolism* is lowered

The inner fires of metabolism actually burn more slowly in old age. It is estimated that the energy used by the body processes when at rest (basal

abnormal conditions (such as irritability of the heart), there is no reason for forbidding their use Much the same may be said of alcoholic beverages McLester has said of them, "In the feeding of elderly persons and those with debilitating disease they are of definite value Such beverages taken with the meal often improve appetite and digestion."[4] Alcohol dilates the capillary blood vessels and thus may improve circulation temporarily. Touhy believes that the abuse of alcoholic beverages by some persons should not detract from their proper uses He says of alcohol "as a vasodilator it inspires as well as flushes the aged," and of tobacco "It soothes and cuts off circulation Tobacco is safer after 60 than before, because age has by that time made the blood vessels less elastic and labile "[5]

RECOMMENDATIONS AS TO DIET

From Forty to Sixty Years

Usually at about 40 to 45 years of age there appears a noticeable *inclination to put on extra weight.* This is due to a decreased amount of *exercise*, to lessened *muscle tonus*, and to diminishing activity of certain *ductless glands*, especially the sex glands, and often the thyroid Although a small increase in weight may be normal, and may even be advantageous in so far as it leads to greater nervous stability, an increase of more than 10–15 pounds in weight during middle age is distinctly disadvantageous and should be avoided Life insurance figures show that above the age of 35 mortality increases about 1 per cent for each pound above optimum weight (see tables of "ideal" weights on p 84 and of desirable weights for 25 years and over, varying with body build, on p 529) There are not many overweight old people because overweight is a predisposing cause to diseases which prevent the overweight person from attaining advanced years.

It is far easier and wiser to cut down moderately on one's fuel intake (and take more exercise) when the tendency to put on weight *first* manifests itself, than to try to take off excess weight by radical dieting or excessive exercising later on Beyond a slight reduction in the amount of fuel foods and some discretion as to the quantities of rich sauces or gravies, fatty foods and other foods hard to digest, no special modification of the diet is needed during this period What has been recommended as the best diet for maintaining the body in health and vigor during younger years continues to be the "optimum diet" in later years. The importance of milk, whole grains, fruits, and green or yellow vegetables as "protective foods" still holds good.

Immoderate indulgence in foods that are of high fuel value or diffi-

[4] McLester, J S, and Darby, W J, NUTRITION AND DIET IN HEALTH AND DISEASE, p 203, W. B Saunders Co, 6th ed, 1952

[5] Touhy, E L, "Feeding the Aged," p 384, in HANDBOOK OF NUTRITION American Medical Association, 1943

so that the *digestive abilities are enfeebled* At the same time, the *liver, kidneys,* and other glands are either *less active* or less able to stand being called on to do extra work. The oxidative processes by which foods are utilized in the tissues go *on more slowly and sometimes less completely,* while the *excretion of excessive waste products* is more *difficult.* The lessened functional ability of these various organs and tissues makes it very desirable that they be spared the strain of handling an *immoderate load.*

A great deal has been said and written recently about the advisability of cutting down on the amount of fat in the diet, especially as one grows older, since the intake of fats and of the lipoid, cholesterol, may be predisposing factors toward the development of arteriosclerosis (hardening of the arteries), high blood pressure, and heart failure due to plugging of the arteries that nourish the heart (*coronary thrombosis*). Some physicians advise limiting the amount of animal fats (those with saturated fatty acids) and taking some of the fat in the form of vegetable oils (which carry more of the unsaturated fatty acids and are more readily metabolized), others favor a diet low in both fats and cholesterol But cholesterol can be made in the body, from the "common pool" of metabolic products contributed to alike by all three foodstuffs (see p 383), so the blood *cholesterol* may remain high in spite of taking none of it in the diet There are numerous factors other than diet which may contribute to circulatory and heart disorders, and it is probable that some of the very restricted diets used (which limit meats and fats decidedly, and cut out milk, butter and eggs entirely) may have done more harm than good Measures to avoid the *development* of high blood pressure and its accompanying disorders should be taken earlier in life, instead of "locking the barn door after the horse is stolen."

A certain amount of fat (with the essential fatty acids) is necessary and makes food more satisfying, but probably it would be a good thing *for most of us to take less fats* Recent surveys show that Americans take an average of 44 per cent of their calories in the form of fats, whereas 20–25 per cent would be a safer amount. Anyway, fats are a prime contributor to overweight, which in itself places an extra strain on the heart and circulatory system. A fairly liberal amount of high quality protein seems to favor longevity, but doubtless too liberal a fat intake has the opposite effect As far as we know, a surplus of calcium, iron, and the various *vitamins are favorable rather than adverse factors even in old age*

A word may be in order concerning the place of mild stimulants such as *tea* and *coffee* or the *moderate* use of *alcoholic beverages* Most elderly persons experience comfort and cheer from hot drinks, and hot coffee or tea slightly stimulates the motility of the digestive tract Their stimulating effect may be welcome to those whose bodily processes are slow and is less likely to be harmful than in younger persons who are under tension They also help to keep up fluid intake. Except in certain

of some such food as hot milk flavored with coffee, hot malted milk, a cup of tea or bouillon, fruit juice, etc—any of them taken with a few crackers)

Use some hot drink or meat broth at beginning of meal to stimulate gastric secretion

Some hot drink such as hot plain or malted milk given before retiring or in the night may relieve wakefulness

A few crackers, a little fruit, or a cup of tea or coffee may be found helpful before rising, especially if the person wakens early

As it is more difficult for the aged to keep warm and digestion is enfeebled, hot foods are welcome and are likely to be more easily digested than cold dishes

When chewing is made difficult because of loss of teeth or because of poorly fitting artificial teeth, the food must be adapted to meet this condition—i e , more liquid or soft, semisolid foods should be given, crisp toast or crackers may be well managed dry or may be softened with broth, milk, coffee, etc , the fiber of cereals, fruits, and vegetables may be softened by cooking, and seeds, skins, and pulp removed by straining, solid foods such as meats may be chopped fine, if necessary

In general, the diet that is best adapted to the alimentary tract of the aged closely resembles that recommended for younger children—namely, milk and eggs, thoroughly cooked cereals (mostly whole grain or enriched), stale bread, toast or crackers, fruits and vegetables (mostly cooked soft but strained or puréed, if necessary), the leaner meats (finely cut if needed), soups, and the simple desserts (custards, blanc mange, cereal puddings, etc) These may be supplemented with easily digested nutriment between meals if desired, and with the addition of such mild stimulants as tea or coffee, which may be helpful or comforting in old age but are not permissible for young children

QUESTIONS AND PROBLEMS

1 What are the two main general ways of holding off the processes of aging and prolonging life? Why do we have a greater proportion of people over 65 in our population now than formerly? What proportion of those over 65 would you estimate are in good enough physical condition to enjoy life?

2 What factors in the diet make for vitality of tissues, and hence longer life? What conditions of diet affect these conditions unfavorably? What are the most common causes of death at present?

3 When should a diet for preventing aging begin? What special changes in dietary régime should be made by persons between 40 and 50 years of age? What are the special dietary needs of people over 60 years of age?

4 Make a list of the foods that should be included daily in the diet

cult to digest, and in salt, condiments, tea, coffee, or other stimulants are indiscretions which must be paid for in time. "There is no greater fallacy than the idea that a man or woman can eat as if finishing himself or herself for the livestock market and at the same time realize many of the worth-while things of life Many individuals do so and then turn themselves over to physicians and beauty parlor experts."[6] The years between 40 and 60 are those when the habitual dietary indiscretions of earlier years are likely to produce their result in indigestion, high blood pressure, hardening of the arteries, disturbances of the heart and circulatory system, diabetes, and kidney disease. Then people flock to doctors in the hope that by some miracle the damage already done can be undone

After Sixty Years of Age

After 60 the diet (1) should be such as to ward off senility, and (2) should be adapted to the lessened needs and functional abilities of the body

1 For the purpose of preventing the degenerative changes in the tissues which commonly develop in old age, the best diet is one which is *moderate in protein and fats*, but one which *promotes intestinal hygiene* and *provides an excess of vitamins and mineral elements.* Although the protein should be moderately liberal in amount, much of it should be of the best quality, such as is provided by milk, eggs, and meat. A diet of moderate fat content makes for easier digestion and keeps the fuel value down to the lowered amount needed in later life. If the intestine is more easily irritated than normal, it may be necessary to strain whole grain cereals or to use highly milled (white) bread and cereals which have been enriched, to give fibrous vegetables strained or finely minced, and to limit fruits to fruit juices, soft raw fruits (such as banana), and the cooked pulp of non-seedy fruits Vegetables may also be given in the form of a purée in soups Fruit juices, especially those from citrus fruits or tomatoes, are all the more important when most vegetables and fruits are cooked, to give the needed quota of vitamin C (ascorbic acid)

2 In *adapting the diet to* the more *feeble bodily conditions* which often prevail in the aged, the suggestions which follow may be used wholly or in part as seems best in individual cases, and the dietary common sense they embody is sufficiently obvious to need no explanation

Cut down the amount of fuel foods consumed considerably below the amount taken in middle life.

Include in the diet only simple, *easily digested foods*, avoid heavy sweets, rich foods, pastries, fried foods, hot breads, etc. Overindulgence in any food which is hard to digest may be a serious matter in old age

Take fewer foods at a meal, eat smaller amounts at shorter intervals (i e , simple meals supplemented by mid-morning or mid-afternoon lunch

[6] McCollum and Simmonds, FOOD, NUTRITION AND HEALTH, 2nd ed , 1928, p 116

Overweight: Its Significance and Treatment

THE PREVALENCE of overweight in the United States is one of our most pressing health problems. Most people enjoy eating and there is plenty of good food. Many accept as normal the gradual accumulation of weight which so often comes in the latter years of life, disregarding the health risks that it brings with it. Some persuade themselves that they are not *much* overweight, just enough to be "pleasingly plump" and it is better to be happy than diet. Others are embarrassed by a mountain of flesh and find it hard to get about, but seem to regard the matter as something determined by fate rather than by themselves. Not all the overweights are middle-aged or over, either. We have overweight young people, children, pregnant women, even overweight babies. One has only to watch the crowds in some public place frequented by the "easy-livers" (such as a good restaurant) to have a graphic demonstration of how large a proportion of our population is overweight.

Everyone should check his weight occasionally with some tables that

of persons 40 to 60 years of age. Plan a day's menus for this age group, including all the essential foods in adequate amounts.

5 What are the special disabilities of the aged? How may the diet be adapted to meet these special disabilities? Plan a day's menus for an 85-year-old man who is in fair health but rather feeble and has lost his teeth (has artificial dentures)

SUPPLEMENTARY READING

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Table 25. Desirable Weights for Men 25 Years of Age and Over*

Height with Shoes		*Weight in Pounds (as Ordinarily Dressed)*		
Feet	*Inches*	*Small Frame*	*Medium Frame*	*Large Frame*
5	2	116–125	124–133	131–142
5	3	119–128	127–136	133–144
5	4	122–132	130–140	137–149
5	5	126–136	134–144	141–153
5	6	129–139	137–147	145–157
5	7	133–143	141–151	149–162
5	8	136–147	145–156	153–166
5	9	140–151	149–160	157–170
5	10	144–155	153–164	161–175
5	11	148–159	157–168	165–180
[illegible]	0	152–164	161–173	169–185
6	1	157–169	166–178	174–190
6	2	163–175	171–184	179–196
6	3	168–180	176–189	184–202

Table 26. Desirable Weights for Women 25 Years of Age and Over*

Height with Shoes		*Weight in Pounds (as Ordinarily Dressed)*		
Feet	*Inches*	*Small Frame*	*Medium Frame*	*Large Frame*
5	0	105–113	112–120	119–129
5	1	107–115	114–122	121–131
5	2	110–118	117–125	124–135
5	3	113–121	120–128	127–138
5	4	116–125	124–132	131–142
5	5	119–128	127–135	133–145
5	6	123–132	130–140	138–150
5	7	126–136	134–144	142–154
5	8	129–139	137–147	145–158
5	9	133–143	141–151	149–162
5	10	136–147	145–155	152–166
5	11	139–150	148–158	155–169
[illegible]	0	141–153	151–163	160–174

* From the Metropolitan Life Insurance Company, March, 1951 Although this is an earlier [illegible]

show the normal weight for his height Tables based on the actual *average* weights of the population at various ages are not so good for this purpose, because so many otherwise normal people show some degree of overweight after forty that these figures are too high to represent the *optimum weight so far as health is concerned.* Physicians and life insurance companies now feel that, for the sake of health and longevity, it is best to carry no more weight in the years after 25 or 30 than is normal for height and body build at that age. The tables given on page 529 are for the "desirable" weights for men and women to maintain at 25 years of age and in later life, modified for three types of body build. Variations of 5–10 per cent over or under the "desirable" weight for height are often normal and of no significance for health But an individual who weighs 15–20 per cent more than the theoretical normal for his or her height must be classed as distinctly *overweight*, while one who is 25 per cent or more overweight can be said to be very fat or *obese*.

Causes of Overweight

The chief causes of overweight may be grouped in three classes:

(1) Overeating,
(2) Inactivity,
(3) Abnormalities of glandular functioning or metabolism; nervous or emotional disturbances.

The first two are the primary causes of overweight, so much so that we can almost class the others as contributory factors People seem very loath to admit to overeating, yet it is an easy thing to do, especially as one grows older and less inclined to physical exertion. Most Americans exercise little, we tend to "spectator sports," to riding in cars, and sitting while we work If appetite and former food habits encourage one to take more food than needed, the flesh accumulates. And only a relatively small excess daily may in time add considerable weight, an extra slice of bread and butter, too large portions of food, or cream and sugar added to foods, may give a *surplus* of energy intake over output that will mean several pounds added in a few months, or 20 to 30 pounds extra weight in a few years time

People who eat gluttonously should be ashamed of it but seldom are, in fact, they will seldom admit it. They will look to any "alibi" to justify themselves, such as "it is in the family to be stout," or "something must be the matter with my glands," or "no matter how little I eat, I don't lose weight." In most cases, a family tendency to stoutness has no more mysterious causes than the liking for "setting a good table," good appetite and digestion, or an easy-going and inactive temperament, combined with food habits such as a preference for sweets and fatty foods or an acquired habit of not feeling satisfied unless the stomach is unduly full. A few people do have an inherited tendency to put on weight more

factor in inducing obesity He could not induce obesity in rats merely by overfeeding them, but if they were kept in such small cages that they were unable to move about, a moderate amount of overfeeding would result in obesity. Some studies on obese children in Boston revealed that most of them did not eat more than normal children but that they were abnormally inactive physically Inactivity is not accompanied by any decrease in appetite and, above a certain basal level, exercise results in no further increase of appetite Mayer concludes "The cost of exercise is, in spite of misguided propaganda, the great variable in energy expenditure Regular physical activity leads to replacement of fat tissue by muscle protein"[3]

Disadvantages of Overweight

The disadvantages of overweight or obesity are sufficiently well known and have been discussed previously (pp 85 and 349), so that we will merely enumerate them here in review

(1) *Inconvenience*—difficulty in getting about, heaviness on feet
(2) *Disfigurement*—embarrassment, sensitiveness to ridicule
(3) *Inefficiency*—lessened muscular activity, lack of ambition, sometimes mental sluggishness
(4) Predisposition to *functional diseases* of the heart, circulatory system, kidneys, and pancreas (diabetes)

Figure 164 This drawing shows strikingly the disadvantages of overweight and the benefits to be derived from reducing to normal weight for height

[3] Mayer, J., "Multiple Origins of Obesity," Nutr News, 17, No 2, Dec, 1953

readily than most people do, and a few do have inactivity of some one or more of the endocrine glands (thyroid, pituitary, or sex glands), but these are distinctly in the minority. Studies on groups of obese people have shown that, in most cases, their basal metabolism is about the same, per unit of surface area, as that in individuals of normal weight. However, their fuel needs are *less* in proportion to their weight than for persons of normal weight, since fat is an inactive tissue and insulates the body from heat loss, and also they exercise very little. In contrast to their lower fuel needs, their intake of energy-bearing foods is high, even though they will not admit it, they forget the rich foods they eat, the between-meal snacks, and the "tastes" of food while cooking It simply takes more self-denial and restraint to keep their weight within bounds than they feel capable of.

Since psychology has come to be much in vogue, physicians have concluded that some persons may overeat to compensate for emotional insecurity or frustration. The child who feels he is not wanted in the home or who fears that the family is likely to be broken up may become a large eater because food symbolizes security to him. The unmarried woman or the wife who feels she is losing her husband's affection may turn to eating to satisfy herself because of unfulfilled emotional desires *Such people need to have the cause of their unusual craving for food explained* and to be made aware of the disadvantages of their behavior. Persons must see advantages to be gained from changing food habits, before they are willing to do so.

Dr Mayer and associates at the Harvard School of Public Health have done some of the most extensive research on the causes of obesity, which they conclude may be the result of many factors They succeeded in breeding strains of rats with a hereditary tendency to obesity, in which they often found abnormalities in carbohydrate or fat metabolism, which in turn they believed to be due to impaired glandular or neural functions. They found that appetite was apparently stimulated when the blood sugar was low, and conversely was less when blood sugar was high, hence, they postulated an "appetite control center" in the brain, sensitive to the level of blood sugar [1] From this they deduced that frequent small snacks, which would keep blood sugar up to normal continuously, would make one satisfied with smaller food intake. This may be so for rats but subsequent experiments with human seemed to show that there was no correlation between the blood sugar levels and the times when the subjects felt hungry or when there were actually hunger contractions in the stomach [2]

Dr Mayer's work emphasizes the importance of physical *activity in* keeping weight down and he believes that lack of it may be a determining

[1] Mayer, J, "An Experimentalist's Approach to the Problem of Obesity," J Am Dietet Assoc 31, 230, 1955

[illegible] ing
et

child must be carefully planned to stint only on calories and to furnish liberally all the nutrients needed for growth—proteins, minerals, and vitamins Usually this means that calorie reduction cannot be as drastic or weight reduction be as rapid as with an adult The re-training in food habits is especially important

FAKE REMEDIES, ADJUNCTS, AND SPECIAL DIETS

Probably no type of quackery is more profitable at present than the special remedies sold to effect weight reduction and various adjuncts supposed to make weight loss easy and safe They flourish because the American public has become conscious of the need to do something about the problem of overweight but still hopes to do it as painlessly as possible So they are credulous about remedies that promise "You can eat all you want and still lose weight" Any manufacturer that makes this promise is banking on the fact that its product contains something that will reduce appetite This may be one of the compounds that take up water and swell, thus creating bulk that will make one disinclined to eat much food, such a product is harmless but most of the swelling and bulk comes in the intestine and, if it has any effect on appetite, it is only an adjunct for which you pay a high price and which has to be reinforced by dietary control to really effect weight loss Or the "remedy" may contain one of the drugs that depress appetite, there are several of these that may be given by physicians but only one or two are allowed to be used without a doctor's prescription, those that can thus be used in preparations on the open market are not potent enough to have any marked effect on appetite, but perhaps taking them has some psychological effect.

Remedies that promise to reduce weight merely by the patient's lying on a vibrating "couch," or to reduce weight in special places so that unsightly bulges will disappear, are so suspect that the federal government agencies are prosecuting many for making false claims The government holds that there is no evidence to show that general weight reduction can be effected by such means alone or that fatty tissue in certain "spots" can be "broken down" and got rid of by such means as massage Systematic exercises for certain muscles may firm the muscles and, if accompanied by dietary control, get rid of extra fat But urgent solicitation to enroll at cut rates for exercises or baths at various establishments for weight reduction should be resisted There can be little or no personal supervision of the exercises and indiscriminate exercising for an overweight individual, who is unused to it and may have back troubles or other ailments, can do harm Baths, including steam baths, can effect little weight reduction except through loss of water from the body, and this can quickly be regained if there is no control over diet, or merely by drinking water. The only type of bath that can be a useful adjunct to weight reduction is the cold shower or plunge, this has

Figure 165 10-year old Iowa school children. All but one in middle are of stocky build and several are overweight Iowa women also showed a high incidence of overweight (Courtesy Dr E Eppright and Iowa State University)

(5) *Lessened expectancy of life*—due to predisposition to functional diseases, and also to fact that fat people have poorer chances of recovery after operations and in serious illnesses.

Overweight is prone to develop at 35–45 years of life (for reasons see p. 523) and is especially disadvantageous after 50 years of age The dangers of overweight are naturally increased with a larger excess of weight and with advancing years For instance, at the period of 40–44 years, 20 per cent excess over normal weight means a 30–40 per cent increase in mortality above the normal for that age bracket, while a 40 per cent excess of weight involves an 80–100 per cent increase in mortality rate Put another way around, a 50-year-old man who is 50 pounds overweight has about half the life expectancy of one of the same age who is of normal weight These figures from the life insurance figures do not lie, and they are quoted here because fat people are so much averse to exercise and dietary self-denial that it seems necessary to frighten them with the serious consequences of overweight before they are willing to undergo the rigors of a reducing regimen.

Obesity in children is not uncommon (see Fig 165) and presents special problems. It handicaps a child socially and at games or sports, to which the overweight child is usually disinclined but may miss being included in group activities Although overweight in childhood does not carry the same predisposition to functional diseases as it does with older adults, if it is not coped with and the child trained to dietary habits that will keep weight down to normal for height, the overweight child will go on to become an obese adult A reducing regimen for a

same foods as the reducer, they are no more effective than any well planned reducing diet, though they may suggest variety and avoid monotony in the diet. People, who would lose patience with a diet that calls for much extra work in food preparation, may go to the other extreme and "fall for" one that involves the minimum of preparation, such as the so-called "formula" diet, which can now be bought already mixed in drugstores One may lose weight fairly rapidly by subsisting entirely on this "formula" (chiefly milk with some sugar added) or on plain milk, but such a diet should not be continued without additional foods for more than a week or ten days, the level of calories and the amount of protein furnished are too low to recommend for any length of time (in addition milk is low in some other nutrients, e g, iron and vitamin C) There are also the peculiar diets based on only a few foods, such as the all-fruit diet, the green-vegetable diet, the pineapple and lamb chop diet, the raw tomato and hard boiled egg diet, etc These appeal to *some people either as short cuts in reducing or as giving distinction* by their unusualness Such diets are not only monotonous to take but are so one-sided that they are sure to be too low in some of the various nutrients Bananas and milk, which supplement each other in nutrients, may be used for two meals of the day provided the third meal consists of meat, low calorie vegetables, salad, or fresh fruit On any of these diets, the size of portions must be limited (i e, the total caloric intake must be kept down) in order to effect weight reduction

PLANNING THE REDUCING DIET

For the ordinary overweight individual, by far the most satisfactory way to effect weight reduction is simply to cut down sharply on the concentrated fuel foods (sugars, starchy and fatty foods), keeping on with an otherwise well balanced and adequate diet Such a diet does not involve actually going hungry, it can be taken over fairly long periods without harm, and it can be continued into the post-reducing period (by adding limited amounts of the foods of higher fuel value) in order to hold the lower weight one has attained by reducing It should be, so far as possible, a diet one likes and is willing to use indefinitely and it should be *inadequate* for body need *in only one respect*, namely its *energy* content

The main things to plan for in any reducing diet are as follows.

(1) Low calorie content
(2) At least adequate protein
(3) At least fairly low carbohydrate and fat
(4) Plenty of minerals and vitamins
(5) Good satiety value

(1) Obviously, to accomplish its purpose, the most important fact about a reducing diet is to have relatively ***low calorie content.*** Just as no

been shown to increase the basal metabolism considerably for some time, provided the individual reacts well after a cold shower, but it is rather "heroic" treatment to which to subject a fat person. Of course, baths and massage are often beneficial for improving circulation and muscle tonus, but will not of themselves effect weight loss, they may be helpful adjuncts to a low calorie diet.

Among the various remedies for effecting weight reduction are rubber garments, pastes, soaps, and bath salts for external use, chewing gums, and tablets and capsules for internal use. The products for external use are ineffective but harmless, while some of those to be taken by mouth may be harmful. Those that do cause weight loss contain some substance like thyroxine or dinitrophenol, which whips up metabolism, and can be dangerous when indiscriminately used. These substances are sufficiently potent that they should be administered only by a physician, with frequent control as to suitable dosage for the individual, and the doctor should do a basal metabolism test to indicate whether the patient really needs thyroxine. Many of these pills, capsules or powders are advertised only as adjuncts to be taken along with a suitable reducing diet. These usually make claims as to being high in proteins, minerals, and/or vitamins, which will safeguard health while on a restricted reducing diet. A few, such as the protein products, either say or imply that they assist in causing weight loss, but the amount of cheap quality protein they furnish in the doses recommended would be of little help. In any event, one pays an exorbitant price and gets no guarantee as to the amounts of the different vitamins and minerals they will furnish, which may be insignificant.

It probably should be emphasized that, while it is entirely possible to get all of the nutrients needed in a well planned reducing diet, supplementary vitamins and minerals may well be a safeguard for persons on drastic or long-continued reducing diets. This is especially true of the fat-soluble vitamins, since fats are sharply curtailed and some persons cannot take large amounts of leafy vegetables. In this case, it is better to buy a reputable vitamin preparation, so that the dosage can be known and controlled.

Lastly, we should take up the special diets for reducing, which are having a great vogue at present. Newspapers and women's magazines have all been carrying such planned diets, with menus for from a week to a full month. It seems remarkable that people should be so eager to follow menu plans made out by someone who cannot know their food preferences or circumstances, or what foods one may be able to obtain readily in local markets. Either they must believe that the diet has some magical properties or they simply want someone else to do all the thinking for them. Usually such diets include some less used foods or foods prepared in unusual ways, they may be relatively expensive and cause extra work, especially if the rest of the family do not wish to eat the

only a little over 300 Cal Thus even foods described as moderately low in calories can raise the caloric intake considerably when taken in large portions All foods furnish *some* calories, except clear soups, tea, coffee, etc. "Counting calories" and deciding what foods one prefers to "spend" *them on can become an intriguing new way of thinking about foods*

All between-meal snacks or extras (such as cream and sugar, salad dressings, etc.) taken in or on foods must be counted in, and this includes cocktails or other alcoholic beverages since both alcohol and sugar in such drinks furnish body fuel. A table of approximate caloric content of servings of alcoholic beverages is given in the Appendix (p 582)

(2) It is important that the reducing diet provide enough *protein* at least for the maintenance and upkeep of body tissues and that the mixture of proteins taken should provide all essential amino acids For the recommended allowance, an adult should have 1 gram of protein per kilogram (2 2 lb) of body weight, and the intake of protein should be at least 50 gm daily for the diet to be adequate Children will need a more liberal protein allowance Naturally, if one cuts down on the foods that are high in carbohydrates and fats, a greater proportion of the calories will tend to be taken as protein In addition (as explained on pp 58–59), the proteins have a stimulating effect on basal metabolism, so that a protein-rich diet will cause a greater "burning" of fuel in body tissues Hence one would lose weight faster on a diet furnishing an inadequate number of calories but liberal protein than he would on the same number of calories when carbohydrates or fats were the chief sources of fuel The luxury diet with meat at every meal of the day is no longer recommended, but the reducing diet may well include one liberal serving of meat per day with either a *small* second serving of meat or one of eggs, fish or poultry, this, together with milk and soft cheeses, will provide liberal protein

(3) The exact distribution of calories between protein, carbohydrate, and fat is not too important, except that protein must be adequate and a *certain amount of carbohydrate is essential* As a practical matter fats are usually sharply limited, they are such concentrated sources of energy (2¼ times as much energy per gram as the other two foodstuffs) that only a small bulk of them can be included without raising the calorie intake too high On a diet inadequate in calories to meet body needs, the body is burning constantly some of its stored fat, under these conditions, fats may not be completely oxidized and the acid intermediate products of their metabolism may accumulate in the body and cause acidosis (excess acid in the body). If small amounts of carbohydrate are included in the low-calorie diet, acidosis will be prevented from developing The inclusion of two or three *thin* slices of bread (without butter), a *small* amount of potato if desired, and/or a small portion of some low-calorie dessert will help to make the reducing diet less harm-

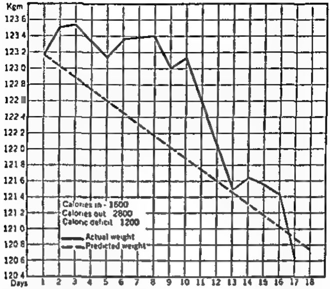

Figure 166 Comparison of actual and predicted weight loss in obese patient on a reducing diet which furnished 1200 calories less than the caloric output During the first ten days there was little weight loss (water retention balanced loss of fat), but in the following week weight loss was so rapid that the total loss equaled the amount predicted (Newburgh and Johnston)

one ever added fat except as the intake of energy exceeded the actual energy needs, so the only way to cause stores of body fat to be consumed is to take a diet that provides less energy than the body requires. One should have an estimate of the normal daily need for energy and plan the diet to furnish from 500 to 1000 calories less than needed This should effect a weight loss of about 3 to 6 pounds a month (the slower weight loss at the higher calorie level) More drastic reductions of the caloric intake will, of course, cause more rapid loss of weight, but it is considered better not to attempt more rapid weight loss than 1 to 2 pounds per week For most adults this will mean a caloric intake of about 1000 to 1600 Cal per day, diets below the level of 1000 Cal (600 to 800 Cal) are too drastic to be recommended, except in extreme cases, and should be administered under the supervision of a physician. Those above the 1600 Cal. level (1700 to 2000 Cal.) give such slow results in weight loss as to be discouraging.

It should be remembered that not only must the choice of foods be right (avoidance of concentrated fuel foods) but the size of portions must be limited, if caloric intake is to be kept down For instance, take the case of the woman, dieting zealously but fitfully, who announced she was having a low calorie breakfast of fruit, she consumed a bumper glass of orange juice (10 oz.), two large pears and a bunch of grapes, which would mean an intake of at least 500 Cal.; two slices of toast with coffee, and *small* portions of thin cream, butter, and sugar would have meant

they take only fluids, fruits, or greens, this tends to shrink the stomach and make them more satisfied on the other days with a smaller volume of food

Lists of foods around which the reducing diet should be built (foods to use), and those which must be avoided if the calorie intake is to be kept low enough to cause appreciable weight loss, are given below

Foods To Use	Foods To Avoid
	Or take only in small amounts
Clear soups	Cream soups
Tea and coffee (without sugar or cream)	Breakfast cereals
Milk (especially skim milk or buttermilk)	Bread
Fresh fruits and canned or stewed fruits without sugar	Starchy vegetables
Watery and fibrous vegetables (especially leafy, green, and yellow vegetables)	Fatty meats
Lean meats, eggs, and soft cheese	Rich dressings and sauces
Small amounts of simple desserts	Rich desserts
	Nuts and dried fruits
	Sugar and sweets
	Cream
	Butter, margarine, or other clear fats

Skeleton Menu for Reducing Diet and How To Use It

It is entirely permissible for anyone to construct his own reducing diet, using whatever foods he has a preference for in such limited amount as will keep the calorie content of the food intake down to a level at which satisfactory weight loss will be obtained

Yet in practice it seems to place too much responsibility upon the individual and to be too confusing to leave him entirely without guidance in the selection of a reducing diet Therefore, we have thought it advisable to suggest a *definite type of meal plan* for those who desire to reduce, leaving considerable latitude for variety and choice of foods in making up individual menus This we have endeavored to accomplish by presenting a skeleton menu for the reducing diet (p 540), with many of the details as to how the menu shall be filled in left open to choice The habit of following a definite meal plan, and acceptance of a certain regularity or monotony in diet as a matter of course, is of great help in making one contented on a more or less limited diet To be always in quest of new food combinations is likely to keep one's mind on food to such an extent that one becomes discontented even with a fairly elaborate diet Hence we believe that the use of the skeleton menu in planning reducing diets may be advantageous in three ways—

(1) Permits choice
(2) Guides food selection
(3) Induces regularity

With regard to directions for using the skeleton menus on page 540, it seems necessary to elaborate mainly in showing *how choice and variety*

ful, as well as more palatable and satisfying. However, it should be remembered that practically all of the energy value of fruits and vegetables comes from the carbohydrates they contain, so that not very much of the more concentrated carbohydrate foods (bread, cereals, and sweets) will be needed to prevent acidosis. One recommendation is that the diet will be well balanced and adequate in all respects except calories if *fruits and vegetables furnish 40 per cent of the total calories*, protein-rich foods 25 per cent, milk 25 per cent, and the remaining 20 per cent are from cereals, bread, sugar, or fats

(4) It goes without saying that a person on a reducing diet should get at least his or her minimum requirements of the various needed *minerals and vitamins*, and probably a surplus of these nutrients may help keep the body in better condition while weight loss is going on This means that any reducing diet should provide liberally for milk, fruits, and vegetables, and that the reduced amounts of bread and cereals taken should be either whole grain or enriched. The meats taken will also contribute B vitamins and iron Skim milk may be substituted for whole milk (it has only about half the calorie value), it will furnish the needed calcium and B vitamins but no fat-soluble vitamins Vitamin A may come from the provitamins in green, leafy, and yellow vegetables, if liberally included If fats are sharply curtailed and large bulk of the green vegetables cannot be taken, probably some vitamin A in capsule form is indicated Many persons who have half starved in order to lose weight rapidly, or who have dieted on very one-sided diets, show evidences of lack of vitamin A or develop anemia Citrus fruits, tomatoes, and other raw fruits and vegetables should be included in order to secure enough vitamin C.

(5) The *satiety value* of the diet is very important if hunger is to be avoided If one took nothing but clear soups, beverages, fruits, and vegetables, he would obtain rapid weight loss but feel very unsatisfied. Fluids and the liberal use of green vegetables give bulk to the diet but are not to be depended upon alone to stave off hunger. Foods which require considerable chewing (crisp toast, crackers, salads, etc) are of some help in making one feel satisfied with a smaller amount of food. *Meat* is one of the foods that can be taken which has a high satiety value, while eggs, milk, and soft cheese will be of some help. Fatty foods, which leave the stomach *most slowly and hence have the highest satiety value*, must be kept down to small amount but a little oil or cheese in salad dressing, or a small piece of hard cheese, may occasionally be included The taking of a small portion of fruit or a simple dessert at the end of a meal will often do much toward making one feel well fed. Some persons are less troubled with hunger if they have a low-calorie snack between meals or at bedtime (such as an apple or orange, a few crackers, or hot skim milk), but these must of course be counted in the total day's calorie allowance. A few people claim that, by having one day a week on which

APPROXIMATE 100 CALORIE PORTIONS OF

Fruits

1 large apple, raw, or small apple, baked with a little sugar, or 1 cup unsweetened apple sauce
1 large orange
½ large grapefruit
Medium large cantaloupe
¾ medium banana
1½ fresh pears (medium)
2 fresh peaches (medium)
Pineapple, fresh, [illegible] slices
1 cup fresh berries

Simple Desserts

Gelatin desserts (plain) } 1 cup
Fruit whip (from fresh fruits) } 1 cup
Sherbets and ices } ⅓ cup
Cup custard } ⅓ cup
Plain blanc mange } ⅓ cup
Cereal puddings } ¼ cup
Ice cream } ¼ cup
Plain cookies, 1 large or 2 small
All desserts should be made not rich nor sweet, served without whipped cream or sauces Scant the measures given above to keep within 100 calories

CHOICE OF WATERY OR FIBROUS VEGETABLES

Average serving 10–50 calories
(approx avg 25 Cal)

Artichokes, French (1)	Celery	Onions
Asparagus	Chard	Parsnips
Beets	Cucumber	Salsify
Beet greens	Dandelion greens	Squash
Broccoli	Eggplant	Spinach
Cabbage	Kale	String beans
Carrots	Kohlrabi	Tomatoes
Cauliflower	Lettuce	Turnip

CHOICE OF OTHER FOODS

Clear soups—Any meat broths or vegetable soups, without rice, noodles, etc Fat should be skimmed off the meat broths

Beverages—Coffee and tea (clear, or sweetened with saccharin)
Whole milk—5 oz (⅝ cup) = 100 calories
Skim milk } —10 oz (1¼ cup) = 100 calories
Buttermilk } —10 oz (1¼ cup) = 100 calories

Breads—Coarse breads such as Graham, whole wheat, or rye breads are usually preferred, but are not essential since most of them have about the same fuel value as white bread, white bread should be of enriched variety

Lean meats—Beef, lamb, mutton, chicken, turkey (roasted or broiled, eat lean portion only)

Lean fish—Cod, haddock, halibut, smelts, trout, whitefish, etc (broiled or baked, not fried)

Eggs—Practically any way but fried or creamed

Cheeses—Best keep to soft cheeses with lower calorie content, or use small amount of Roquefort cheese in salad dressing, or small amount of grated cheese as flavoring on vegetables

Salads—All green salads may be used liberally (lettuce, endive, escarole, romaine, chicory, cress, etc)

Any combination of the fresh fruits and the watery or fibrous vegetables listed above may be used in salads, e g, apple and celery, shredded cabbage and

Other

SKELETON MENU FOR REDUCING DIET

Approx 1100–1400 Calories

	Calories
Breakfast.	
Fruit	100
2 very thin (¼ in) slices crisp toast (no butter)*	65
2 cups coffee with hot skim milk (about half and half), no sugar*	60–85
	225–250
Luncheon:	
1 cup clear soup	25
1 egg, *or* small serving lean meat or fish	65–135
1 slice bread (½ in thick), toast, or small roll	65
Large serving green salad with lemon juice or vinegar	15
Cheese, 1 in cube solid cheese, or 2 level tablespoonfuls cream cheese, or ¼ cup cottage cheese	80–105
Fruit (without sweetening), *or* small portion simple dessert	100
	350–445
Dinner.	
1 bowl clear soup; 1 cracker	50
1 large serving lean meat or fish	150–275
2 servings low-calorie vegetables (about 25 calories each) *or* 1 serving vegetable and 1 small potato (2¼ in diam)	50–100
Salad—green salad, dressing with vinegar and small amt. oil, *or* —small portion salad of low-calorie vegetables or fruits, with small amount cooked salad dressing	50–75
Dessert—fruit without sugar *or* small portion simple dessert	100
Beverage—½ cup coffee with ½ cup hot milk, *or* 1 glass buttermilk or skim milk, or ⅔ glass whole milk	80–110
	480–710

* If
so by cut
or 1 tbsp
diet, how
concentrated foods

may be effected. Variety may be introduced through using equivalent-calorie portions of different fruits, vegetables, soups, meats, beverages, cheese and egg dishes, salads, and desserts, as suggested in the lists on page 541 [4]

Varying the Calorie Content of the Diet

The range of calories suggested in the skeleton menu is from 1100 to 1400 calories It will be apparent that the fuel value of the diet may readily be varied within this range, raised above 1400 Cal , or reduced even below 1100 Cal if desired, by simple *additions or subtractions from*

[4] Although the calorie value of the foods in any one group is not exactly equivalent (or may not be exactly 100 Cal), it is nearly enough so that they may be substituted without materially altering the calorie intake for the day In the skeleton menu and discussion, calories for average servings are rounded off to the nearest values ending in 5 or 10.

the reasons why it is necessary to follow some definite plan of meals in order to get good results

GENERAL RULES FOR REDUCING REGIMEN

1 *Those who should reduce—*

Normal persons who are 20 per cent or more overweight

Persons 10–15 per cent overweight, if they have a tendency to heart disease, kidney disease, gout, or diabetes, should reduce to normal weight, or even slightly less

Persons over 40 years old, who have put on excess weight, may with profit reduce to their normal weight for 25 or 30 years of age

Persons who are of normal weight, or only slightly over normal, should *not* attempt weight reduction

2. *How to find out the proper level of food intake to use for reducing*

Calculate your maintenance level (i e, the calorie intake necessary to maintain

active (adults require 15–20 Cal per lb per day)

This gives the maintenance level of calorie intake

Plan the diet to yield 500–1000 Cal per day *less* than the maintenance level, depending on how rapidly you want to lose weight

EXAMPLE A woman 5 ft 5 in tall, 25 years old, and of medium frame should weigh about 127–135 lbs (actually weighs 167 lbs, about 25

$2000 - 700 = 1300$ calories

Reducing diet for this individual should furnish 1300–1600 Cal

3. *How to determine how much to reduce food level in order to get a certain rate of weight loss*

One oz body fat represents approximately 275 Cal of food

If you cut down food intake 500 Cal below maintenance level, you should lose about ¾ lb per week, or 3 lb per month

Cutting down 700 Cal below maintenance level should result in weight loss at rate of a little over 1 lb per week, or 4 lb per month

A reduction of 1000 Cal below maintenance level will cause weight to be lost at rate of 1 lb 8 oz per week, or approximately 6¼ lb per month

You may not lose exactly at the calculated rate each week, especially the first week or two, but in the long run the weight loss will average about that expected, if you stick to your diet

4 *Weighing and best rate at which to lose*

5. *Dangers of too rapid reduction*

May cause weakness, difficulties of heart and other organs, and throws a severe strain on the system for rapid readjustments in any event

the menu. To attain the lower level of 1100 calories, one would have to use the smallest portions indicated throughout, or else leave out some of the suggested foods. For example, omitting the fruit from breakfast, a slice of bread and the cheese from lunch, and dessert from dinner would reduce the fuel value by about 350 calories One could then either keep to the lower level of food intake, use the extra calories by taking larger portions of some of the other foods included in the skeleton menu, or introduce 350 calories in the form of some food not suggested here It is better, however, to stick to the type of foods suggested and to raise the calorie level by taking more liberal servings. All sorts of different combinations can be made, according as it is desired either to alter the form in which a given number of calories is taken, or to raise or lower the level of the calorie intake[5] The 1100–1400 calorie level makes a good reducing diet for most women (see paragraph on proper calorie level to use in reducing on page 543) Men usually need a slightly higher level of calories than women (1500–2000 Cal), because of their larger size.

Altering the Meal Plan

The reducing diet can readily be altered so as to allow of a different arrangement of meals from the one suggested here. Some regular system of meals should be adopted, however, and strictly adhered to, as only thus will a reducing diet yield the desired results Moreover, it is almost essential that at least *one meal in the day should be very light* in order to keep to the low calorie level.

For those who like a heavier breakfast, an egg (75 Cal) *or* a small serving of cereal with ¼ cup milk (not top milk or cream and no sugar) can be added to the breakfast suggested, and either lunch or dinner made lighter by the omission of 75–150 Cal in some form.

Others will prefer to take the heaviest meal in the middle of the day, while some who find it hard to carry out a reducing diet at the table with those eating a full diet may think it best to make two meals *very* light, taking them separately, and thus save enough of their calorie allowance for a full meal with the family at noon or night. In order to eat one good square meal (approx 800 Cal), however, on a 1200 Cal daily quota, one would have to limit one's self very strictly on the other two meals (say 100 Cal for breakfast and 300 Cal for lunch, or 200 Cal for each meal), which ordinarily will mean more hardship than to have the food allowance more evenly divided

Although the level of calorie intake does not have to be *absolutely* the same each day, it is essential that the meal plan be such that the fluctuations made by choice in foods used will cause it to vary only within narrow limits (extreme variations not over 200–300 Cal.). This is one of

[5] More exact calorie values for average servings of most of the common foods are to be found in Table 28 in the Appendix, pages 574 to 581.

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Detrimental to looks, as skin is apt to become wrinkled after the rapid loss of subcutaneous fat

I ... as the very restricted diet necessary will probably cause ...

A ... ss hardship and will leave one in far bette...

6 *Necessity of keeping at lower level of food intake after reducing diet*

It should be obvious that, if you go back to the former food level on which you gained weight, you will regain the weight which has just been lost.

When you have lost the desired amount of weight on a restricted diet, increase the food intake *gradually* until *you are taking just enough food to maintain constant weight* Keep the food intake at this new level *If you begin to gain,* cut down the diet by a small amount

With most normal individuals the level of food intake, which must be kept to in order not to regain weight, will not be sufficiently low to cause any hardship once one is accustomed to the new habits, with persons inclined to stoutness, extra care and restraint as to food habits will be necessary.

QUESTIONS AND PROBLEMS

1 Give four reasons why persons become overweight, how do you tell how much overweight a person is, and what are the dangers and difficulties of excess weight?

2. Is there any way (or ways) to reduce weight except by restriction of calories in the diet? What foods should be avoided or used only in small amounts in a reducing diet, and why? What foods may be used in quantity, and why? In which nutritive factor (or factors) must the reducing diet be low, and in which should it be adequate or better than adequate? Why? What food groups in the diet assure its adequacy?

3 Following the general meal pattern on page 540, plan a reducing diet that will be adequate for all body needs except fuel, and furnish about 1400 calories Revise this diet so as to drop out 400 Cal. and still have the diet adequate for body needs of an average adult, except for calories

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Malnutrition: How to Detect and Overcome It

Malnutrition vs. Underweight

These terms are not synonymous, though the two conditions often occur together. Underweight results from an intake of calories insufficient to meet the body's energy needs, just as overweight results from a surplus caloric intake. Malnutrition is a broader term, it means poor nourishment, or that the tissues have been getting an insufficient supply of one or more nutrients essential to keep them in healthy condition. Persons who are much underweight are usually in malnourished condition, because when they cut down on food intake they not only have a shortage of calories but also of various other nutrients. On the other hand, one sees persons not infrequently who are up to or even above normal weight

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upon in times of extra stress The fatty tissues not only serve as reserve fuel but as padding about the nerve plexuses and to buoy up and keep in place the abdominal organs. The very thin person has a scrawny appearance and tendency to chill easily (due to lack of a normal layer of subcutaneous fat), is nervously high strung, tense and irritable, and often suffers from nervous indigestion, constipation, and a variety of ill-defined ailments Such persons have poor appetite, poor tone of the muscles of the digestive tract, readily experience both mental and physical fatigue, and are more liable to nervous diseases and infection (especially tuberculosis) Their basal metabolism may be lowered and they are disinclined to any physical exertion, for their bodies are conserving energy. This is what we call living on a "lower nutritional level" Contrast their condition with that of an athlete or man who does physical labor, they both consume and spend calories at a high level, but have fine muscle tone, are much more vigorous and happier

The disadvantages of becoming accustomed to living on a low level of caloric intake were pointed up by some experiments on otherwise healthy people Years ago Dr F G Benedict made a study of the effect of sharply reduced caloric intake on healthy young men, and this type of study was repeated during World War II on a group of 32 conscientious objectors at the University of Minnesota by Keys and associates In both cases, the young men, who had previously taken well over 3000 Cal daily, submitted to a drastic reduction of caloric intake until they had lost body weight on an average of 12 per cent in the earlier set of experiments and 24 per cent in the later ones Their weight was then kept stable on a somewhat higher but still restricted calorie level (1950 Cal in Benedict's group, 1550 Cal in Keys' experiments) At this lower nutritional level the men reported that they felt well but had less energy and had to drive themselves to do their accustomed tasks, and they gave out sooner in various gymnasium tests Keys' subjects subsisted on the low level of calories for six months and developed some more serious symptoms—depression, anemia, edema, slowing of heart beat, etc. They showed marked lack of endurance, tired easily, and reduced unnecessary movements to a minimum When returned to their former level of caloric consumption, they recovered their vitality, but it took considerable time to restore them to buoyant health [2]

So we see that, even for healthy young men, living on a lowered nutritional level has numerous disadvantages, even dangers For young women, who restrict calories with a view to having a very slender figure, it may be even more dangerous The current fad of girls and young women for reducing weight, below what is normal for their height and build is held responsible for the recent increase of tuberculosis among this age group, when it was falling off decidedly in other age groups.

[2] Keys' experiments are reviewed in Chapter 19, "Caloric Undernutrition and Starvation," in the A.M.A HANDBOOK OF NUTRITION, 2nd ed., 1951.

but show signs of malnutrition; their food has supplied enough calories but not enough of protein, minerals, or vitamins.

The latter type of persons, either children or adults, usually have a good-sized body and enough subcutaneous fat so that they may look well nourished to the superficial observer. The weight increase is due chiefly to extra fatty tissues and also somewhat to water held back in the tissues, rather than to the building of muscles, organ tissues, or bones. They may be found among the poor, whose low income forces them to fill up on the cheaper energy-giving foods (starchy foods, cheaper fats and sweets) and does not allow them to buy enough of the "body-building" foods (meat, milk, fruits, and vegetables). They may almost as often be found among the well-to-do, who simply prefer to eat the wrong types of food. Their color is usually poor, their flesh flabby, their bones and teeth of poor quality. They are often *anemic* and *listless*, tire quickly, take infectious diseases readily, and, when seriously ill, are more apt to succumb than persons who have better nourished tissues and greater vitality. It is in these ways that their malnourished condition shows.

Underweight may or may not be serious, depending upon the degree of underweight and the age at which it occurs. The average weights (found in tables) are not necessarily the normal or the best for every individual. There are times when it is advantageous to be somewhat under the average weight for height, this is true of persons, middle-aged or older, especially if they have any tendencies to high blood pressure, heart or kidney ailments. Life insurance companies tell us that for older adults a slight degree of underweight increases health and life expectancy. This does not mean underweight to the point of malnutrition, some older people, especially those of small means, live on such skimpy or one-sided diets as to lead to serious malnutrition However, it is with *children* and *young adults* that underweight is almost sure to be a disadvantage and may be dangerous to health In general, we may say that to be as much as 7–10 per cent below the average weight for one's height and type of body build[1] usually means lowered vigor and physical efficiency while to be more than 10 per cent underweight is apt to mean a reduction of vitality and stamina such as may be dangerous.

Disadvantages and Dangers of Underweight

Normally the body profits from having some stores of fatty tissue, as well as reserves of the other nutrients which can be stored, to draw

[1] The average weight of boys and girls at given heights and ages will be found in the Appendix (pp 588–593), with variations to be expected according to whether

upon in times of extra stress. The fatty tissues not only serve as reserve fuel but as padding about the nerve plexuses and to buoy up and keep in place the abdominal organs The very thin person has a scrawny appearance and tendency to chill easily (due to lack of a normal layer of subcutaneous fat), is nervously high strung, tense and irritable, and often suffers from nervous indigestion, constipation, and a variety of ill-defined ailments. Such persons have poor appetite, poor tone of the muscles of the digestive tract, readily experience both mental and physical fatigue, and are more liable to nervous diseases and infection (especially tuberculosis) Their basal metabolism may be lowered and they are disinclined to any physical exertion, for their bodies are conserving energy. This is what we call living on a "lower nutritional level" Contrast their condition with that of an athlete or man who does physical labor, they both consume and spend calories at a high level, but have fine muscle tone, are much more vigorous and happier.

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Many insist they feel all right, but fatigue easily, and have no energy for extra exertions. Later, if they enter the period of pregnancy without any of the normal body reserves, the effect on themselves and their babies may be disastrous. In Europe, during and after the long period of underfeeding in World War II, there was an increase of still births and of babies who died soon after birth, tuberculosis and other infectious diseases flared up among both young mothers and children during the postwar years Even today, among the poor in the teeming populations of Asia, the Middle East, Africa, Southern Italy, and South America, there are millions who exist on a very low nutritional level because of insufficiency of calories (complicated by shortage of other nutrients) and we see the results in lack of ambition, general misery and disease.

Malnutrition Defined and *How To Detect It*

Malnutrition may be described as a state in which either *the food intake is inadequate in some respect* to meet the body needs, or in which physiological and environmental *conditions are such that the body is unable to utilize sufficient food materials* to provide for its proper growth, maintenance, and repair. Such a deficiency will be ***most likely to occur and to be most serious in youth,*** when the demands for calories to meet the high basal metabolism and muscular activity, and for building materials and calories to cover the growth needs, are much greater proportionally than in adult life.

It should be recognized that malnutrition may be brought about in many different ways. The food may be inadequate either as to *quantity* or *quality*, or the food supply may be all right, but *digestion* and *absorption* be so poor that the food materials are not taken into the blood stream, a disabled heart may fail to pump the blood to the tissues properly or other factors may interfere with good *circulation* in the tissues Some factor like *adenoids* or bad *posture* may prevent a good reoxygenation of blood in the lungs *Living habits or environment*, which react upon the individual so as to bring about poor appetite, aversion to particular foods or refusal to take food, poor digestion, overfatigue, etc, are naturally unfavorable to nutrition, as are also absorbed toxins from various *infections* in the body In short, anything which tends to make the food intake lacking in some essential material or low in total amount, and anything which interferes with the normal processes by which food is utilized in the body, will tend to bring about a malnourished condition, which will be more or less severe depending upon the *extent* of the deficiency thus brought about

We usually *detect* malnutrition by certain outward *signs* which are the effects produced by that condition It would seem to be an easy matter to tell whether a person is well or ill nourished, and it is true that to the trained eye such differences in nutritive condition seem obvious and are quickly noted. However, it must be remembered that

there are all degrees of malnutrition, and that the average individual is not apt to look at himself or his own child with unprejudiced eyes The child is merely a little delicate, or plays so hard that he couldn't get fat, or is in the stage where he is growing tall so he is naturally thin, or inherits his father's lean tendency These are well worn alibis for refusing to recognize malnutrition as such In practically all such cases extra weight could be put on and health improved by increasing the food intake and correcting the bad habits or physical defects responsible for malnutrition.

Often the parent assumes that the child is all right because he has no high standard of what a healthy child should be For this reason, a list of some of the more striking *characteristics* of the *well nourished* individual, contrasted with those usually found in *malnourished* individuals, is given. The student should observe carefully the pictures of children in good and poor nutritive condition shown below and on page 552, and compare them with the characteristics listed in the outline on

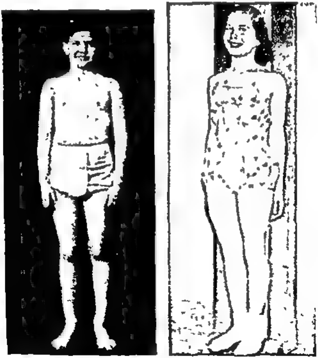

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Figure 167 A. A well nourished 10-year-old boy who has practically all the characteristics of good nutrition listed in the text (Roberts, NUTRITION WORK WITH CHILDREN, University of Chicago Press) B, A well nourished Iowa girl, also 10 years old, who is obviously healthy (Courtesy Dr E Eppright and Iowa State University.)

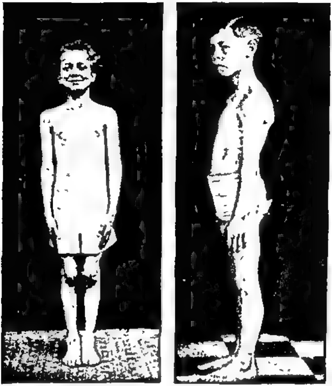

Figure 168 Two examples of poor nutrition chosen to show different types.

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page 553, to see how completely those children illustrate the signs of good or poor nutrition as enumerated in this list.

Nowadays physicians and school nurses are trained also to look for signs of deficiency of any specific vitamin They observe the eyes carefully for inflammation about the cornea that may be the result of riboflavin deficiency and ask if there is difficulty in seeing in dim light (result of vitamin A deficiency) They look carefully at the mucous membranes of the mouth and at the tongue for signs of deficiency of niacin or riboflavin They inquire as to appetite, and test nerve reflexes as a clue to deficiency of thiamine They sometimes take x-ray pictures of bones to see whether ossification has been or is taking place satisfactorily (especially in the ends of bones), and an unsatisfactory picture will indicate lack of enough vitamin D or calcium, or both

These are visible signs, but we can go even further in order to detect milder grades of malnutrition Chemical analyses of the blood may be made to determine whether a low level of any certain vitamin in blood points to insufficient supply of one or several vitamins Excretion

CHARACTERISTICS OF

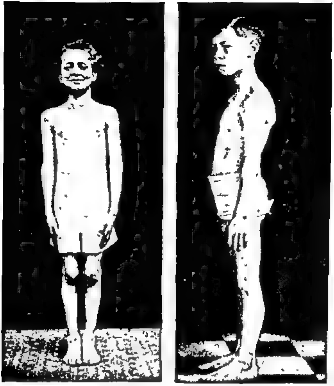
Good Nutrition	Malnutrition
Well developed *body*	Body may be undersized, or show poor development or physical defects
About average *weight* for height	Usually thin (underweight 10 per cent or more), but may be normal or overweight (fat and flabby)
Muscles well developed and firm	Muscles small and flabby
Skin turgid and of healthy color	Skin loose and pale, waxy or sallow
Good layer *subcutaneous fat*	Subcutaneous fat usually lacking
Mucous membranes of eyelids and mouth reddish pink	Mucous membranes pale
Hair smooth and glossy	Hair often rough and without luster
Eyes clear and without dark circles under them	Dark hollows or circles under eyes
Facial expression alert but without strain	Facial expression drawn, worried, old or animated, but strained
Posture good: head erect, chest up, shoulders flat, abdomen in	Fatigue posture: head thrust forward, chest narrow and flat, shoulders rounded, abdomen protruding
Good natured and full of life	Irritable, overactive, fatigues easily *or* Phlegmatic, listless, fails to concentrate
Sleep sound	Difficult to get to sleep, or sleeps restlessly
Digestion and *elimination* good	Subject to nervous indigestion, constipation
Appetite good	"Finicky" about food
General health excellent	Susceptible to infections
	Lacks endurance and vigor

of the vitamin in the urine can be determined after giving a test dose of it, excretion of an abnormally small proportion of the vitamin given indicates that it has been taken up instead by the blood and tissues which had too low a supply because of lack of that vitamin in the diet These tests work especially for the water-soluble vitamins, and we rely especially on such means to see to what extent the body is or is not "saturated" with ascorbic acid (vitamin C)

Prevalence of Malnutrition

The estimation of the amount of malnutrition that exists in the country will depend on the standards set for good nutrition If one takes only those who are markedly underweight or show gross signs of poor physical condition, the numbers may be reassuringly few If one goes to the other extreme and classes everyone as malnourished in whom chemical tests show that the body is not "saturated" with certain vitamins (especially vitamin C), a lot of apparently healthy people will be included and the numbers will be alarmingly large

The statement is often made that about 30 per cent of our population is malnourished, although conditions vary in different sections of the country, at different economic levels, and according to the stand-



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discussion, they have been presented in outline form below.* This has the additional advantage of showing at a glance how different causes are related. In view of the fact that we are concerned in this book chiefly with the dietary factors, these are given in slightly greater detail, but it must not be assumed that they are more important. While it is usually necessary to locate and remove *several* faulty habits or defects which are operating jointly to cause the poor state of nutrition, almost *any single factor*, if sufficiently severe and long continued, will produce malnutrition. An effort should be made to correct physical defects, faulty health habits and unfavorable environmental conditions, so that all conditions may be as favorable as possible for making nutritive gains, i.e., to *remove unfavorable factors* so that the individual is *"free to gain"* when the diet is altered for the better.

- Causes of malnutrition
  - Direct causes
    - Faulty diet
      - Too little food
        - Lack of appetite
        - Inadequate breakfast or lunch
        - Not enough food provided
        - Low calorie foods chosen
      - Food inadequate in kind
        - Too little milk
        - Too few vegetables and fruits
        - Too much candy and other sweets
        - Use of coffee and tea
      - Bad food habits
        - Between-meal eating
        - Hurried meals
        - Irregular meals
    - Faulty hygiene
      - Too little sleep
      - Too little fresh air and sunshine
      - Chronic fatigue
      - Bad posture
    - Defects and disease
      - Bad tonsils or adenoids
      - Bad teeth
      - Tuberculosis
      - Syphilis
      - Other infections
      - Hookworm
  - Underlying causes
    - Ignorance
    - Lack of home control
    - Poverty

The *underlying causes* of malnutrition in children have been stated to be *ignorance, lack of home control,* and *poverty*. These are the home or community conditions responsible for the factors that cause the malnutrition. The two first named are probably the more prominent, for malnutrition is by no means confined to homes where the income is low. On the other hand, if one has not the money to buy enough food or to provide more expensive but essential foods such as milk, fruits, and vegetables, it is impossible to prevent malnutrition. Lack of ability to realize cause and effect relations, prejudices against certain foods or hygienic measures, ambition of parents to push children too hard at school or in outside activities, refusal to recognize the condition for what it is, ignorance of how to go about remedying it, are all variations of the ignorance factor.

* This outline is condensed (with slight alterations) from a chart showing the causes of malnutrition and their relationship, contained in "Roberts' Nutrition Work with Children," Univ. of Chicago Press, 3rd ed., revised by E. A. Martin, 1954.

ards used in judging malnutrition When surveys are made of family food supplies or foods consumed by individuals (dietary records), and the results are judged by comparison with the "yardstick" of recommended allowances of the National Research Council's Food and Nutrition Board, the conclusions are apt to be misleading. These allowances were set as a reasonable "optimum" toward which we should strive for the betterment of nutrition, they include a "margin of safety," so that a person whose intake of certain nutritive factors is not up to the recommended allowance is by no means necessarily malnourished (although he may be if the shortage is too great)

Since malnutrition is most apt to occur in growing children and the proper nutrition of our children is a matter of great concern, we may briefly note a few surveys, keeping in mind the cautions as to conclusions noted above Wiehl[3] examined the diet histories of some 2000 high-school pupils in New York City, 28 per cent were getting less than two-thirds of the calcium allowance (Food and Nutrition Board); 38 per cent were getting less than two-thirds of the vitamin A allowance, and 25 and 29 per cent fell below the two-thirds level of riboflavin and ascorbic acid, respectively Many got less than the full allowances for some or all nutritive essentials, but the deficiences mentioned above were the most serious Mack and co-workers[4] made studies on 575 children, some in an industrial community and some in a college town Those in the industrial section ate less of the "protective foods" than those in the college community, but there were some even in the better educated families who were consuming too little of these foods, even amounts so inadequate as to lead to malnutrition Surveys of school children too numerous to cite, surveys based only on underweight and visible evidences of malnutrition, have given evidence that about a fifth of these children were malnourished even by these standards

However, taking the population as a whole (both adults and children), the latest dietary surveys of the Dept of Agriculture[5] indicate that only 10 per cent or less of the households surveyed had diets that furnished less than two-thirds of the recommended allowances of various nutrient essentials and recent surveys of school children also show that their diets are more adequate than formerly Individual cases of severe malnutrition still occur and, in this country, we are trying not only to eradicate gross malnutrition, but to raise the nutritional status and health of all the people

Causes and Prevention of Malnutrition

As it is necessary to point out the causes of malnutrition in small space here, and since they are sufficiently obvious and common to need little

[3] Wiehl, D G, Milbank Mem Fund Quart, 20, 61, 1941

[4] Mack, P B, *et al*, J Am Dietet Assoc, 18, 69, 1942

[5] "Dietary Levels of Households in the United States," U S Dept Agric, Household Food Consumption Survey, Report No 6, 1957

will in time effect a considerable reduction in the prevalence of malnutrition.

Treatment of Malnutrition

Although numerous organizations are endeavoring to see that the present generation of infants and small children have a better start in life, from a nutritional standpoint, than many of their older brothers and sisters did, we have a great many cases of *established* malnutrition among both children and adults, which should receive *treatment*. In order to be effective, this treatment must follow two lines

1. *Location and removal of the contributory causes of malnutrition*
2. *Improvement of the diet.*

Under the first heading comes a thorough study of the person's *daily program* to discover whatever faulty food and health habits there may be, and a general *medical examination* to see whether there are any physical defects which need to be corrected. These unfavorable factors that predispose to poor nutrition must then be remedied—bad habits of living corrected, physical defects and disease receive proper treatment. Often considerable persistence may be needed to locate *all* the causes which are holding the individual back from gaining. *Overfatigue* is one of the most common causes and is easily corrected by longer hours of sleep, rest periods during the day, and reducing the activities which cause the fatigue. Persons with more severe or with less obvious malnutrition will often require continued observation and study by a physician, or in a nutrition clinic or class, in order to locate and treat the factors responsible for keeping the person below par physically.

Feeding a suitable diet is perhaps the most important single measure for improving malnutrition—certainly an adequate food supply is indispensable. The corrective diet may be started at once—i.e., while one is in the process of locating and clearing up the unfavorable contributory factors as outlined above. While the body may not be able to take *full* advantage of the upbuilding diet until all the adverse factors are remedied, the diet given meantime should be of the best type, and this in turn may help to remedy defects and diseased conditions more quickly, and to strengthen the tissues and organs so that they will function better. A body which has been depleted by prolonged underfeeding will require building up in numerous respects. Not only should new deposits of *fat* be laid down, but the muscles are in need of *protein* (rich in essential amino acids) for repair and enlargement, extra *iron* is often needed for the blood, and the bones may never have calcified properly (due to poor diet) or they may have been robbed of *calcium* and *phosphorus* to meet the current insufficiency, so that there will be need for an increased supply of these mineral elements and of *vitamin D* to assist in their utilization. Reserve stores of *vitamins* are used up or

The lack of home control is patent among wealthy, middle class, and poor alike, although possibly more prevalent at the two extremes of economic status. The children of the rich are apt to be overindulged and left to the care of servants who have little interest or authority, while the children of the poor are deprived of supervision and left to fend for themselves because the parents are at work. Moreover, Americans are noted for laxness with their children and undue indulgence of the children's whims "Life for many undisciplined children is one unbroken series of dissipations," says Emerson, and a prominent child specialist estimated that 85 per cent of his cases were fundamentally due to this cause of lack of parental control. Of course, once parental control has been lost, it is difficult to reestablish it sufficiently to carry out any health program, even with the best of intentions on the parents' part, so that securing cooperation of the child himself is essential But why place such a responsibility upon the shoulders of inexperienced children? Parents do not usually allow children to decide what they will wear, whether they will take music or dancing, and what they will study at school, but they do constantly leave the children to decide what they will or will not eat, and when they will go to bed.

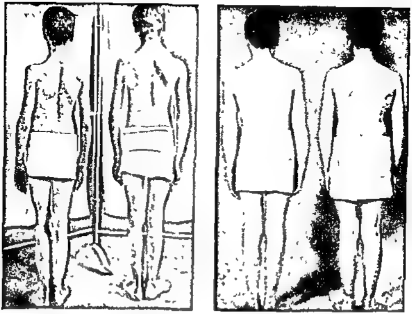
This leads us to the subject of the *prevention* of malnutrition This is an extremely important subject which can be discussed only briefly, but we hope that the classification and discussion of the causes of malnutrition given above will make more or less obvious the measures necessary to correct it or to prevent its occurrence The *direct* causes (see outline, p 555) must be gotten rid of and the conditions responsible for them (*underlying causes*) must be remedied, so far as is possible. The family with an income insufficient to buy suitable food must receive help through some proper agency, educational propaganda of various sorts must be used to make people realize the prevalence of malnutrition and its causes, either the parents must take charge in some constructive health program for the child, or the child must be guided by teaching in the schools to reorganize its own diet and habits of living so that these factors will be favorable to good nutrition.

The chief agencies, through which such educational and remedial measures have been carried out, are individual advice of physicians, books and magazine articles, mothers' clubs, infant and prenatal clinics, nutrition classes and general instruction in diet and hygiene given in the schools, and the work of various child welfare organizations School lunches have been an important factor by supplying supplementary food for children of low-income groups and teaching good food selection to all, even to the mothers who may take part in the project. Until recently child welfare work has been chiefly dependent on private contributions, but now various federal, state, and city agencies have been created and empowered to spend public funds for the betterment of child health One may expect that these enlarged efforts in behalf of public health

The first requirement is met by including in the diet *liberal* amounts of the *concentrated fuel foods*, especially foods rich in *fats, sugars*, and *starches*, such as butter or margarine, cream, salad dressings, bacon, cereals, bread, sugar, cream soups, high-calorie desserts, legumes, nuts and dried fruits—in short all the list of foods forbidden to *overweight* individuals Filling foods that carry little nourishment (e g clear soups) and much fluid with meals should be avoided Fat meats, pastries, rich sauces and gravies should be used only in moderate amounts There is danger of *digestive disturbances* when so much concentrated food and so much fat is being taken, so that fats are best given in the more *easily digested* forms. Protein of high quality, for tissue building and repair, is provided by including liberal amounts of *milk*, with *eggs* and *meats* as freely as expense permits Organ meats, such as liver which are excellent sources of minerals and vitamins, should be taken frequently Even though they may seem to increase the bulk of the diet undesirably, plenty of *fruits* and *vegetables* should be included for their content of mineral elements, vitamins, and fiber Milk eggs, and whole grain or "enriched" bread and cereals are also valuable sources of mineral salts and vitamins Although *high calorie content* is thus the *main objective* of the diet, care should be taken that it provides an *abundance of all the other nutritive essentials* as well

The diet should provide *energy in excess of body needs* by at least a 500–1000 calorie surplus The calorie intake may be increased above body needs to the extent of $\frac{1}{3}$–$\frac{1}{2}$ of the energy required for maintenance, e g, a person who needs 2100 Cal for maintenance should take approximately 2800–3150 Cal when trying to put on weight It is often necessary to force one's self to take food in excess of one's appetite, and sometimes to keep on taking it in spite of minor digestive disturbances The food may be well utilized due to the effectiveness of the later stages of digestion, and nothing helps more toward greater nervous stability (hence less nervous indigestion) than taking on extra weight It will be necessary that the *concentrated fuel foods* (those with high calorie content) occupy a prominent place in the diet, in order to provide large amounts of energy without having the *bulk* of food uncomfortably large Fatty foods, which are so high in fuel value, may be taken in considerable amounts, if well tolerated It is easy to increase the energy intake considerably by such devices as an extra square of butter or fortified margarine at each meal (about 220 Cal), liberal use of cream, bacon, and salad dressings (1 tbsp mayonnaise, 2 tbsp thick cream, or 2 heaping tbsp whipped cream each furnish about 100 Cal), 1 tbsp salad oil after each meal (370 Cal), and supplementary nourishment between meals or at bedtime

The best foods to use for the *mid-morning or mid-afternoon lunch* are *milk, eggs,* and *fruit juices* These can be served in many combinations, e g, plain cold milk enriched with a little cream, hot malted milk



A B

Figure 169 Effects of treatment for malnutrition The two boys (*A*) were refused working certificates because they were seriously underweight Their backs present ... blades and ...onforms to ...efore they ...nd general ... CHILDREN,

lost from the body during semistarvation, and we know that an excess of vitamins in the diet is a help in the upbuilding processes necessary to repair after malnutrition For these reasons, we prefer to speak of the special diet that should be given in malnutrition as an *upbuilding* rather than a *fattening* diet, although the most striking effect of such diets is to cause the individual to put on weight through the deposition of fatty tissue The important features of such a diet are described more fully below.

CHARACTERISTICS OF UPBUILDING DIETS

From the discussion in the foregoing paragraph it should be apparent that the diet suitable for building up a body, which has suffered for some time from an insufficient food supply, should be planned so as to provide

(1) A *high energy intake*—fuel in excess of body needs, which will be stored as fat

(2) Liberal quantities of ***high quality protein.***

(3) An *abundant* supply of ***mineral elements and vitamins.***

SAMPLE MENU FOR AN UPBUILDING DIET

(For Adult with Energy Requirement of about 2400 Calories)

	Calories *(approximate)*
BREAKFAST:	
Orange juice, 8 oz. glass	110
Wheatena with figs (2)	200
and cream (⅔ c thin)	250
1 egg	77
Toast, whole wheat, [illegible] slices	110
with butter or margarine (1 tbsp.)	100
and jam (1½ tbsp.)	90
Coffee, sugar (1 tbsp.)	48
	1015
10.30 A. M.—1 glass milk (enriched with ¼ c. thin cream)	240
LUNCHEON	
Creamed chicken on toast	260
Lettuce and tomato salad with mayonnaise dressing	135
Bread, whole wheat (1 slice) and butter or margarine (1 tbsp.)	155
Ice cream (½ c.)	200
Cocoa (1 c.)	175
	925
4.00 P. M.—1 glass malted or chocolate milk	220
DINNER	
Cream vegetable soup	150
2 crackers	[illegible]
Roast lamb (liberal serving)	270
Baked potato (medium-sized)	100
with butter or margarine (1 tbsp.)	100
Peas (avg. serving) Cream spinach (avg. serving)	100
Waldorf salad (med. serving)	140
Lemon meringue pie	280
	1190
Total	about 3600

are the best aids to building up the muscle tissues. Stores of calcium phosphate in the bones and of hemoglobin in the blood may also need rebuilding. Some concentrated iron preparation and supplementary vitamins (capsules of vitamin A and D, also of the B-complex vitamins with vitamin C added) may be needed and helpful in the earlier stages of upbuilding, but later on those supplied in the diet should be sufficient. A steady weight gain of about 2 pounds per week is a moderate goal for which to strive.

The increase in *health, endurance,* and *nervous stability,* which usually parallels the weight increase, is often amazing and is ample reward for persistence in an upbuilding regimen.

or milk flavored with chocolate or cocoa, eggnog, or beaten egg in fruit juice, fruit juice plain or with extra calories added in milk sugar or malt sugar (which are not very sweet). These foods are *easily* and *quickly digested*, and hence are not so likely to upset digestion or spoil the appetite f[illegible] meats, relishes, and tasty desserts are often helpful from this point of view.

An *illustrative menu* for a fattening, upbuilding diet is given on page 561. The approximate number of calories furnished is included, as of interest in showing how rapidly the *fuel value* of the diet will mount when fats and concentrated starchy foods are included in any considerable quantities. The meals alone, as planned in this diet, will furnish over 3100 Cal., or 700 Cal. in excess of the energy needs of a sedentary man (2400 Cal.) without seeming unduly bulky. Supplementary nourishment between meals (as indicated) may be used to further increase the fuel intake by 460 Cal., and more supplemental calories may be taken, if desired.

GENERAL REGIMEN FOR INCREASING WEIGHT

The success of any regimen for increasing weight depends chiefly on getting the individual *to take sufficient amounts* of a *high calorie diet*, while he simultaneously *cuts down muscular activity and tenseness* by taking *extra rest* and *relaxation*. It is often best to keep such persons in bed for a time, especially those who are much run down, or who find it very difficult to put on weight. Those who have little appetite, or who have developed fears that foods will cause digestive distress, must often force themselves to take food in excess of their natural desires at first. If this is done, the general condition will usually improve to such an extent that both the appetite and digestion will return to normal. Taking thiamine in tablet form may stimulate appetite and improve digestion by promoting better muscle tone of the alimentary tract. Rest is a very important factor, both in preventing the fuel intake from being burned up too rapidly and in securing better utilization of the food through improved digestion.

Rapid gains in weight should not be the main objective of the upbuilding program, as such gains are usually due solely to the deposition of *fat* in the body, whereas it is much to be desired that the muscle tissues also should be built up. *Muscle development* is favored by a more gradual gain in weight on a diet containing plenty of the best quality protein (milk, eggs, and meat). In addition, *massage* to stimulate circulation in the muscles will be a help while the patient is in bed, when up and about, *out-door life* and some form of light but regular *exercise*

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QUESTIONS AND PROBLEMS

1. What are the outward signs of good nutrition and a healthy body? In what respects does a malnourished individual differ from a well-nourished one, and how can the average person detect malnutrition? What tests can the doctor or nutritionists make to detect lesser grades of malnutrition?

2. How prevalent is severe malnutrition in the United States? How prevalent are lesser degrees of malnutrition? What are the disadvantages and dangers of malnutrition, in major degree and in minor degree? Why is it more prevalent among children?

3. What are the essential points in an effective diet for upbuilding of the body and putting on weight? What kind of a regimen will reinforce the good effects of the diet? What benefits may be expected from such a diet and regimen?

4. *Plan a fattening and upbuilding diet that will furnish 3500 calories for a person with good appetite and digestion. Modify it to give the same* fuel value for a person whose digestion is feeble and appetite poor.

SUPPLEMENTARY READING

Books

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Appendix

It should be understood that there is considerable variation in the composition of foods, especially in their vitamin content. Cooked foods are even more variable in composition than raw foods, due to variations in recipes, in fat and moisture content, and in amounts of vitamins lost in cooking. Figures given in the table on the following pages (565–591) represent either average or mean values, i.e., those most likely to be approximated in a majority of cases. The source of these figures is the U. S. Department of Agriculture Handbook No. 8, COMPOSITION OF FOODS—RAW, PROCESSED, PREPARED, compiled by the Bureau of Human Nutrition and Home Economics and published in June, 1950. Figures for some cooked foods and prepared food products are taken from Bowes and Church, FOOD VALUES OF PORTIONS COMMONLY USED, 7th ed., 1951.

Since the National Research Council's recommended allowances for vitamins are given in milligrams, vitamin content of foods has been stated in these units except vitamin A, which is expressed in International Units. If desired to convert milligrams to micrograms (whole numbers), simply move decimal point three places to right, e.g., 0.100 milligram = 100 micrograms.

Although in the figures for cooked foods given in Table [illegible] (pp. 568–591), deductions for vitamin losses in cooking have already been made, readers may be interested in the tabular summary below, showing the average losses of the different vitamins that may be approximately expected during different methods of cooking raw foods.

Food	Raw Vitamin Value Lost in Cooking				
	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
	per cent	per cent	per cent	per cent	per cent
Cereals		2–35			
Bread		10–15			
Eggs		[illegible]			
Meats					
Frying		15		15	
Broiling		30	15–20 (any method)		
Roasting		40–50		[illegible] (stewing)	
Vegetables					
Leafy	20	25 (all kinds)	10–15 (all kinds)	15 (all kinds)	45
Green or yellow					40
Potatoes	7				20
Others	5				35
Fruits.					30–40 (more if baked)

Abbreviations used in Table 28: E. P., edible portion, A. P., as purchased, tr., trace.

Table 27. Recommended Daily Dietary Allowances,[1] Food and Nutrition Board, National Research Council, Revised 1958

DESIGNED FOR THE MAINTENANCE OF GOOD NUTRITION OF HEALTHY PERSONS IN THE U S A.

(Allowances are intended for persons normally active in a temperate climate)

	AGE YEARS	WEIGHT KG. (LB)	HEIGHT CM (IN)	CALORIES	PROTEIN GM	CALCIUM GM	IRON MG	VITAMIN A I U	THIAM MG	RIBO MG.	NIACIN[2] MG EQUIV.	ASC ACID MG.	VITAMIN D I U.
Men	25	70 (154)	175 (69)	3200[3]	70	0.8	10	5000	1.6	1.8	21	75	
	45	70 (154)	175 (69)	3000	70	0.8	10	5000	1.5	1.8	20	75	
	65	70 (154)	175 (69)	2550	70	0.8	10	5000	1.3	1.8	18	75	
Women	25	58 (128)	163 (64)	2300	58	0.8	12	5000	1.2	1.5	17	70	
	45	58 (128)	163 (64)	2200	58	0.8	12	5000	1.1	1.5	17	70	
	65	58 (128)	163 (64)	1800	58	0.8	12	5000	1.0	1.5	17	70	
	Pregnant (second half)			+300	+20	1.5	15	6000	1.3	2.0	+3	100	400
	Lactating (850 ml daily)			+1000	+40	2.0	15	8000	1.7	2.5	+2	150	400
Infants[4]	0–1/12[4]				See Footnote 4								
	2/12–6/12	6 (13)	60 (24)	kg × 120		0.6	5	1500	0.4	0.5	6	30	400
	7/12–12/12	9 (20)	70 (28)	kg × 100		0.8	7	1500	0.5	0.8	7	30	400
Children	1–3	12 (27)	87 (34)	1300	40	1.0	7	2000	0.7	1.0	8	35	400
	4–6	18 (40)	109 (43)	1700	50	1.0	8	2500	0.9	1.3	11	50	400
	7–9	27 (60)	129 (51)	2100	60	1.0	10	3500	1.1	1.5	14	60	400
	10–12	36 (79)	144 (57)	2500	70	1.2	12	4500	1.3	1.8	17	75	400
Boys	13–15	49 (108)	163 (64)	3100	85	1.4	15	5000	1.6	2.1	21	90	400
	16–19	63 (139)	175 (69)	3600	100	1.4	15	5000	1.8	2.5	25	100	400
Girls	13–15	49 (108)	160 (63)	2600	80	1.3	15	5000	1.3	2.0	17	80	400
	16–19	54 (120)	162 (64)	2400	75	1.3	15	5000	1.2	1.9	16	80	400

[1] The allowance levels are intended to cover individual variations among most normal persons as they live in the United States under usual environmental stresses The recommended allowances can be attained with a variety of common foods, providing other nutrients for which human requirements have been less well defined

[2] Niacin equivalents include dietary sources of the preformed vitamin and the precursor, tryptophan. 60 milligrams tryptophan equals 1 milligram niacin

[3] Calorie allowances apply to individuals usually engaged in moderate physical activity For office workers or others in sedentary occupations they are excessive Adjustments must be made for variations in body size, age, physical activity, and environmental temperature.

[4] The Board recognizes that human milk is the natural food for infants and feels that breast feeding is the best and desired procedure for meeting nutrient requirements in the first months of life. No allowances are stated for the first month of life Breast feeding is particularly indicated during the first month when infants show handicaps in homeostasis due to different rates of maturation of digestive, excretory and endocrine functions Recommendations as listed pertain to nutrient intake as afforded by cows' milk formulas and supplementary foods given the infant when breast feeding is terminated Allowances are not given for protein during infancy

Beef											
Hamburger, med., cooked.	80	1 patty, 4 from a pound	291	17.6	7	2.2	0	0.06	0.14	3.8	0
Rib roast, cooked.	100	1 sl., 4½ x 3 x ½ in	319	24.0	10	3.0	0	0.06	0.18	4.1	0
Round, steak, cooked	100	1 pc., 4½ x 3½ x ½ in.	233	27.0	11	3.4	0	0.08	0.22	5.5	0
Sirloin, steak, cooked	100	1 pc., 4 x 2½ x 1 in	297	23.0	10	2.9	0	0.06	0.19	4.8	0
Beet greens, cooked	100	½ cup	27	2.0	*	3.2	7,440	0.05	0.16	0.4	15
Beets, fresh, cooked	100	½ cup diced, or 2 beets 2 in diam	41	1.0	21	0.7	[illegible]	0.02	0.04	0.3	7
Biscuits, baking powder	[illegible]	1 avg., 2 in diam., or 2 small	109	2.4	19	0.5	20	0.[illegible]	0.07	0.6	0
Blackberries, fresh .	100	⅔ cup, 4 rounded tbsp	57	1.2	32	0.9	200	0.04	0.04	0.4	21
Blueberries, fresh	100	⅔ cup	61	0.6	16	0.8	280	0.02	0.02	0.3	16
Breads											
Boston brown	35	1 sl., 3 in diam x ½ in.	71	1.7	64	1.3	34	0.07	0.07	0.5	0
Corn Southern	35	1 piece, 2 in square	139	3.2	29	0.7	229	0.09	0.10	0.7	0
French or Vienna	20	1 slice, average	54	1.6	5	0.4	0	0.05	0.03	0.4	0
Raisin	23	1 slice, average	65	1.6	18	0.4	tr	0.06	0.04	0.5	0
Rye, American	23	1 slice, average	57	2.1	17	0.4	0	0.04	0.02	0.4	0
White, unenriched	23	1 slice, average	63	2.0	18	0.1	0	0.01	0.02	0.2	0
White, enriched	23	1 slice, average	63	2.0	18	0.4	0	0.06	0.04	0.5	0
Whole wheat	23	1 slice average	55	2.1	23	0.5	0	0.07	0.03	0.7	0
Broccoli, cooked	100	2 stalks, med or ⅔ cup	29	3.3	130	1.3	3,400	0.07	0.15	0.8	74
Brussels sprouts, cooked	70	6 average	33	3.1	24	0.9	280	0.03	0.08	0.4	33
Butter	10	1 pat, average	[illegible]	0.1	2	0	330	tr	tr	tr	0
Butter	14	1 tbsp	100	0.1	3	0	460	tr	tr	tr	0
Cabbage, headed											
raw	50	½-¾ cup, shredded	7	0.6	[illegible]	0.45	130	0.01	0.02	0.2	15
cooked	100	¾-1 cup	14	1.2	43	0.9	260	0.02	0.03	0.3	[illegible]
Cake											
Angel	45	1 piece, 1/10 of avg cake	121	3.8	3	0.15	0	tr	0.06	0.1	0
Chocolate, rich, 2 layer .	100	1 pc., iced, 1/12 of avg. cake	[illegible]	4.4	88	0.5	690	0.02	0.07	0.2	0
Cup, iced .	[illegible]	1 medium	161	2.6	58	0.2	140	0.01	0.03	0.1	0
Plain, 2 layer .	[illegible]	3 in sector, fudge icing	314	4.0	88	0.4	390	0.02	0.07	0.2	0
Cantaloupe or muskmelon, E P	150	½ of 4½ in melon, or ⅔ cup balls	30	0.9	25	0.6	5,130	0.07	0.06	0.7	50

* Calcium present is mostly in nonutilizable form.

Table 28. Nutritive Values of Foods in Average Servings [illegible] Common Measures

Food	Weight	Approximate Measure	Calories	Protein	Minerals		Vitamins				
					Calcium	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic acid
	gm			gm.	mg	mg.	I U	mg.	mg.	mg.	mg.
Almonds, shelled	15	12–15 nuts	90	2 8	38	0 7	0	0 04	0 10	0.7	tr.
Apples, fresh, E P	125	1 medium, 2¾ in diam	72	0 4	7	0 4	112	0 05	0.04	0.25	6
Apples, baked	115	1 large, 2 tbsp sugar	213	0 6	12	0 6	180	0 03	0 04	0.3	2
Applesauce, sweetened	100	½ cup, scant	72	0 2	4	0.4	30	0 02	0.01	tr.	1
Apricots, fresh	100	2–3 medium	51	1 0	16	0.5	2,790	0 03	0.05	0.8	7
canned, sirup pack	100	4 halves, 2 tbsp. juice	80	0 6	10	0.3	1,350	0 02	0.02	0.3	4
canned, water pack	100	4 halves, 2 tbsp. juice	32	0 5	10	0.3	1,350	0 02	0.02	0.3	4
dried, sulfured	30	4–6 halves, raw	79	1.6	26	1.5	2,230	tr.	0 05	1.0	4
dried, sulfured, cooked, unsweetened	100	4 halves, 2 tbsp juice	85	1.7	28	1 6	2,420	tr	0 05	1.0	3
Artichoke, French, A P	200	1 large	51	2 8	39	1 0	190	0 09	0 03	0	9
Asparagus, fresh, green	100	5–6 large stalks, cooked	[illegible]	2 4	19	1 0	1,040	0 13	0.17	1.2	23
Asparagus, canned, green	100	6 med stalks, drained	21	2 4	19	1 9	800	0 06	0 08	1 0	18
Avocado, Fuerte variety	100	½ of 3½ in, pear	245	1 7	10	0 6	290	0 06	0 13	1 1	16
Bacon, med fat, broiled	25	3 strips, 6 in long, crisp	152	8 2	8	0 8	0	0 12	0 08	1 [illegible]	0
Bananas	125	1 medium	110	1 5	10	0.75	[illegible]	0 05	0 06	0 9	12
Bass, average, baked	115	1 avg serving, 3 x 3 x ½ in	287	23 6	96	1.2	97	0 07	0 16	3 5	0
Beans, baked, canned with pork and molasses	130	½ cup	162	7 5	73	2 7	45	0 16	0 04	0 6	3
Beans, lima, fresh . .	80	½ cup, steamed	76	4 0	23	1 4	230	0 11	0.07	0 9	12
Beans, soy, dried (dry wt)	30	½ cup, scant, cooked	[illegible]	10 4	68	2 4	33	0 32	0 09	0.7	tr.
Beans, snap, green, fresh	100	¾ cup, cooked	22	1 4	36	0 7	660	0 07	0 10	0 5	14

Beans, snap green, canned...	100	½ cup, drained solids	22	1.4	16	1.7	400	0.04	0.05	0.4	5
Beef											
Hamburger, med., cooked.	80	1 patty, 4 from a pound	291	17.6	7	2.2	0	0.06	0.14	3.8	0
Rib roast, cooked	100	1 sl., 4½ x 3 x ½ in	319	24.0	10	3.0	0	0.06	0.18	4.5	0
Round, steak, cooked	100	1 pc., 4½ x 3½ x ½ in	233	27.0	11	3.4	0	0.08	0.22	5.5	0
Sirloin steak, cooked	100	1 pc., 4 x 2½ x 1 in	297	23.0	10	2.9	0	0.06	0.19	4.8	0
Beet greens, cooked	100	½ cup	27	2.0	*	3.2	7,440	0.05	0.16	0.4	15
Beets, fresh, cooked	100	½ cup diced, or 2 beets 2 in diam.	41	1.0	21	0.7	20	0.02	0.04	0.3	7
Biscuits, baking powder	35	1 avg., 2 in diam., or 2 small	109	2.4	19	0.5	20	0.09	0.07	0.6	0
Blackberries, fresh	100	⅔ cup, 4 rounded tbsp	57	1.2	32	0.9	200	0.04	0.04	0.4	21
Blueberries, fresh	100	⅔ cup	61	0.6	16	0.8	280	0.02	0.02	0.3	16
Breads											
Boston brown	35	1 sl., 3 in diam. x ½ in	71	1.7	64	1.3	34	0.07	0.07	0.5	0
Corn, Southern	35	1 piece, 2 in square	139	3.2	29	0.7	229	0.09	0.10	0.7	0
French or Vienna	20	1 slice, average	54	1.6	5	0.4	0	0.05	0.03	0.4	0
Raisin. .	23	1 slice, average	65	1.6	18	0.4	tr	0.06	0.04	0.5	0
Rye, American.	23	1 slice, average	57	2.1	17	0.4	0	0.04	0.02	0.4	0
White, unenriched	23	1 slice, average	63	2.0	18	0.1	0	0.01	0.02	0.2	0
White, enriched	23	1 slice, average	63	2.0	18	0.4	0	0.06	0.04	0.3	0
Whole wheat	23	1 slice, average	55	2.1	22	0.5	0	0.07	0.03	0.7	0
Broccoli, cooked	100	2 stalks, med., or ⅔ cup	29	3.3	130	1.3	3,400	0.07	0.15	0.8	74
Brussels sprouts, cooked	70	6 average	[illegible]	3.1	24	0.9	280	0.03	0.08	0.4	33
Butter	10	1 pat, average	[illegible]	0.1	2	0	330	tr	tr	tr	0
Butter	14	1 tbsp	100	0.1	3	0	460	tr	tr	tr	0
Cabbage, headed											
raw	50	½–¾ cup, shredded	7	0.6	22	0.45	130	0.01	0.02	0.2	15
cooked	100	¾–1 cup	14	1.2	43	0.9	260	0.02	0.03	0.3	22
Cake											
Angel	45	1 piece, 1/10 of avg. cake	121	3.8	3	0.15	0	tr	0.06	0.1	[illegible]
Chocolate, rich, 2 layer	100	1 pc., iced, 1/12 of avg. cake	378	4.4	88	0.5	690	0.02	0.07	0.2	0
Cup, iced	[illegible]	1 medium	161	2.6	58	0.2	140	0.01	0.03	0.1	0
Plain, 2 layer.	90	3 in. sector, fudge icing	314	4.0	88	0.4	390	0.02	0.07	0.2	0
Cantaloupe or muskmelon, [illegible]	150	½ of 4½ in. melon, or ⅔ cup balls	30	0.9	25	0.6	5,130	0.07	0.06	0.7	50

* Calcium present is mostly in nonutilizable form.

Table 28. Nutritive Values of Foods in Average Servings or Common Measures (Continued)

Food	Weight	Approximate Measure	Calories	Protein	Minerals: Calcium	Minerals: Iron	Vitamins: Vitamin A	Vitamins: Thiamine	Vitamins: Riboflavin	Vitamins: Niacin	Vitamins: Ascorbic acid
	gm			gm	mg	mg	I U	mg	mg	mg	mg
Carrots											
raw	[illegible]	1 carrot, 5½ x 1 in., or ½ cup grated	[illegible]	0.6	20	0.4	6,000	0.03	0.03	0.3	3
cooked	100	1 large, or ¾ cup cubes	30	0.6	26	0.6	12,500	0.05	0.05	0.4	4
Cauliflower, cooked	100	¾ cup	25	2.4	22	1.1	90	0.06	0.08	0.5	[illegible]
Celery, raw, bleached	50	2 stalks or hearts	9	0.6	25	0.25	0	0.03	0.02	0.2	4
Cereals											
Bran Flakes, 40%, Kellogg	30	¾ cup	97	3.0	16	1.1	0	0.11	0.07	2.4	0
Corn Flakes, Kellogg	30	1⅓ cups	109	2.2	1	0.5	0	0.12	0.03	0.6	0
Cornmeal, yellow											
unenriched	30	¾ cup, cooked	104	2.2	2	0.3	85	0.04	0.01	0.3	0
enriched	30	¾ cup, cooked	104	2.2	2	0.8	[illegible]	0.12	0.07	1.0	0
Cream of Wheat											
regular, unenriched	30	¾ cup, cooked	102	3.5	10	1.1	0	0.02	0.02	0.2	0
5 minute, enriched	30	¾ cup, cooked	100	3.4	143	12.0	0	0.15	0.03	0.4	0
Oatmeal, or rolled oats	30	¾ cup, cooked	111	4.0	15	1.3	0	0.17	0.04	0.3	0
Ralston, instant, enriched	30	⅔-¾ cup, cooked	100	3.5	14	8.5	0	0.42	0.04	1.5	0
Rice, puffed, Quaker	30	1 cup	[illegible]	1.8	4	0.6	0	0.15	0.01	1.5	0
Wheatena	30	⅔ cup, cooked	101	2.9	8	0.1	0	0.04	0.04	1.1	0
Wheaties	30	1 cup	105	2.9	7	1.3	0	0.15	0.04	1.5	0
Wheat, puffed Quaker	12	1 cup	44	1.6	3	0.5	0	0.07	0.02	1.2	0
Wheat, shredded	30	1 large biscuit	102	2.9	13	1.0	0	0.06	0.03	1.3	0
Chard, Swiss, cooked	100	½ cup stalks and leaves	21	1.4	*	2.5	3,110	0.04	0.06	0.4	17
Cheeses											
Cheddar, American	20	1 pc 2 x 1 x 1½ in., or 2 tbsp grated	[illegible]	5.0	145	0.2	280	tr	0.[illegible]	tr	0
Cheddar, American	30	1 ounce	113	7.1	206	0.3	400	0.01	0.12	tr	0
Cottage	30	1 rounded tbsp., or ⅛ cup	[illegible]	5.5	27	0.1	10	0.01	[illegible]	tr	0
Cream	30	1 ounce, or [illegible] level tbsp	106	2.6	19	0.1	410	tr	0.06	tr.	0
Cheese products											
Spread, Kraft's *pimento*	30	*1 ounce*	63	2.3	17						
Velveeta	30	1 ounce	92	5.2	173						

Cherries, fresh	100	20–25 small, 15 large	61	1.1	18	0.4	620	0.05	0.06	0.4	8
Cherries, red, canned, sirup	100	½ cup	105	0.6	11	0.3	430	0.03	0.02	0.1	3
Cherries, canned, water pack	100	½ cup	51	0.8	11	0.3	120	0.03	0.02	0.1	3
Chicken Broiler, fried, E P	85	¼ bird, fortified margarine used in frying	232	22.4	■	1.8	230	0.07	0.17	9.7	0
[illegible] ned meat	100	½ cup, scant	199	29.8	14	1.8	0	0.04	0.16	6.4	0
[illegible]	177	¾ cup avg serving	312	26.4	124	1.6	490	0.06	0.23	5.7	tr
[illegible]	100	3 sl., 3½ x 2½ x ¼ in	198	28.3	20	2.1	0	0.08	0.18	9.0	0
[illegible] dive, curly	■	10 small leaves, avg. serving	3	0.4	20	0.4	750	0.02	0.03	0.1	3
[illegible] tter	30	1 ounce or 1 square	142	1.6	*	1.2	17	0.01	0.07	0.3	0
[illegible] ilk	30	1 ounce, plain	154	2.4	57	0.7	43	0.03	0.14	0.1	0
[illegible] ams	13	1 avg. pc (35 to 1 lb)	51	0.5							
[illegible] lge, plain	30	1 pc, 1½ in square	118	0.5	14	0.2	64	tr	0.02	tr	
[illegible] everage) all milk	200	1 cup, small, 6 oz milk	192	6.6	208	0.4	280	0.06	0.32	0.2	2
[illegible] d	100	½ cup, solids and liquids	51	7.9	67	6.3	80	0.05	0.10	1.1	
[illegible]	170	1 bottle, 6 oz	78								
[illegible] rage), all milk	200	1 cup, small, 6 oz. milk	190	7.6	238	0.8	320	0.08	0.38	0.4	2
[illegible] aked	■	4 oz before cooking	170	18.7	11	0.5	0	0.05	0.09	2.1	tr
[illegible]	3.7	1 tsp U S P Min Standard	33				3,145	plus 314 I U Vitamin D			
[illegible] ked	100	½ cup	40	3.9	249	1.6	7,630	0.08	0.24	1.7	44
[illegible] rted, plain	25	1 large, or 4 small	109	1.5	6	0.15	0	0.01	0.01	0.1	0
[illegible] cooked	100	1 medium ear	85	2.7	5	0.6	390 yellow tr white	0.11	0.10	1.4	8
Corn, sweet, canned	*100*	*½ cup, drained solids*	*85*	2.7	4	*0.5*	200 yellow tr white	*0.03*	0.05	0.9	5

* Calcium present ■ mostly in nonutilizable form.

Table 28. Nutritive Values of Foods in Average Servings [illegible] Common Measures (Continued)

Food	Weight	Approximate Measure	Calories	Protein	Minerals: Calcium	Minerals: Iron	Vitamins: Vitamin A	Vitamins: Thiamine	Vitamins: Riboflavin	Vitamins: Niacin	Vitamins: Ascorbic acid
	gm			gm	mg	mg	I U	mg	mg	mg	mg
Corn grits, yellow, cooked unenriched	100	½ cup, scant	51	1.2	1	0.1	40	0.02	0.01	0.2	0
[illegible]	100	½ cup, scant	51	1.2	1	0.3	40	0.04	0.03	0.4	0
[illegible] der Cereals											
[illegible]	20	1 tbsp	57	0	9	0.8	0	0	tr	tr	0
[illegible] d or cooked	80	½ cup	83	13.5	36	0.7		0.04	0.05	2.0	
[illegible]	7	1 cracker, 2½ in square	27	0.5	1	0.15	0	0.02	0.01	0.1	0
[illegible]	6.5	1 double wafer	21	0.8	3	0.3	0	0.02	0.01	0.1	0
[illegible]	4	1 cracker, 2 in square	17	0.3	1	0.05	0	tr	tr	0.05	0
[illegible]	20	1 rounded tbsp, sweetened	47	tr	tr	tr					
[illegible] whipping	15	1 tbsp	49	0.3	12	tr	220	tr	0.02	tr	tr.
[illegible] whipping	60	¼ cup, or 4 tbsp	196	1.2	48	tr	880	tr	0.08	tr	tr
[illegible] %	15	1 tbsp	[illegible]	0.4	15	tr	120	tr	0.02	tr	tr.
[illegible] %	[illegible]	¼ cup, or 4 tbsp	122	1.7	58	0.02	495	0.02	0.08	0.05	tr.
[illegible]	50	½ medium	6	0.4	5	0.2	0	0.02	0.02	0.10	4
[illegible]	157	One, 4 from 1 pint milk	205	8.8	163	1.1	607	0.08	0.31	0.10	0
[illegible] s, cooked	90	½ cup	38	2.4	168	2.8	13,650	0.11	0.11	0.65	15
[illegible] resh	[illegible]	3–4 stoned	85	0.6	[illegible]	0.6	[illegible]	0.03	0.03	0.65	0
[illegible] t	[illegible]	1 average	121	1.9	15	0.4	67	0.06	0.05	0.5	tr
[illegible]	31	1 medium	15	3.3	[illegible]	0.1	0	0	0.08	tr	0
[illegible]	17	1 medium	61	[illegible] 8	25	1.2	550	0.05	0.06	tr.	0

Egg, whole, raw	54	1 medium	77	6.1	26	1.3	550	0.05	0.14	tr	0
omelet plain	62	1 egg, milk added	120	6.6	44	1.3	726	0.04	0.15	tr	0
scrambled	[illegible]	1 egg, 1 tbsp milk, 1 tsp fat	123	6.6	44	1.3	726	0.05	0.16	tr	0
Eggplant, plain, cooked	100	½ cup, or 2 slices	24	1.1	15	0.4	30	0.04	0.05	0.6	5
Escarole, raw	50	2 large leaves	10	0.8	40	0.9	5,000	0.03	0.06	0.2	6
Fats, cooking vegetable, solid	100	½ cup	884								
Fats, cooking, vegetable, solid	12.5	1 tbsp	110								
Figs, fresh	100	2 large or 3 small	[illegible]	1.4	54	0.6	80	0.06	0.05	0.5	2
canned, sirup pack	114	3 figs, 2 tbsp sirup	129	0.9	40	0.5	60	0.03	0.04	0.4	1
dried	21	1 large	57	0.8	39	0.6	20	0.03	0.02	0.4	0
Flounder or Sole, raw	113	1 serv 4 ounces	[illegible]	16.9	69	0.9		0.07	0.06	1.9	
Flours											
Rye, light	[illegible]	1 cup, sifted	285	7.5	18	0.9	0	0.12	0.06	0.5	0
Wheat patent, all purpose, unenriched	110	1 cup, sifted	401	11.6	18	0.9	0	0.07	0.05	1.0	0
enriched	110	1 cup, sifted	401	11.6	18	3.2	0	0.48	0.29	3.8	0
Wheat, whole grain	120	1 cup stirred	400	16.0	49	4.0	0	0.66	0.14	5.2	0
Fruit cocktail, canned	128	½ cup, solids and liquid	90	0.5	11	0.5	205	0.01	0.01	0.45	2
Gelatin dry, plain	10	1 tbsp	34	8.6							
Gelatin dessert, plain	120	½ cup, as served	77	1.9							
Gelatin, dessert, with fruit	120	½ cup, as served	86	1.7	7	0.35	135	0.03	0.02	0.25	3
Gingerbread (hot water and 1 egg)	57	1 pc 2 x 2 x 2 in	206	2.2	45	1.4	69	0.06	0.05	0.5	0
Grapefruit, E P	188	½ medium, 4½ in diam	75	0.9	41	0.4	20	0.07	0.04	0.4	76
Grapefruit juice, canned unsweetened	180	6 oz , ¾ cup, 1 sm glass	69	0.9	15	0.5	15	0.05	0.03	0.3	64
sweetened	180	6 oz , ¾ cup 1 sm glass	98	0.9	15	0.5	[illegible]	0.05	0.03	0.3	64
Grapefruit and orange juice, canned, unsweetened	184	6 oz., ¾ cup, 1 sm glass	74	1.1	16	0.5	82	0.08	0.03	0.4	[illegible]
Grapes, American, E P	100	22–24, average size	55	1.1	13	0.5	60	[illegible]	0.03	0.2	3

Table 28. Nutritive Values of Foods in Average Servings [illegible] Common Measures (Continued)

Food	Weight	Approximate Measure	Calories	Protein	Minerals: Calcium	Minerals: Iron	Vitamins: Vitamin A	Vitamins: Thiamine	Vitamins: Riboflavin	Vitamins: Niacin	Vitamins: Ascorbic acid
	gm			gm	mg	mg	I U	mg	mg	mg	mg
Grapes, Malaga, Tokay, or green seedless	100	22–24 avg size, or 60 green seedless	66	0 8	17	0 6	[illegible]	0 06	0 04	0 2	4
[illegible] al	190	6 oz, ¾ cup, 1 sm glass	127	1 7	19	0 6		0 07	0 08	0 45	tr.
[illegible] mix	45	1 medium, 4 [illegible] diam	62	2 3	96	0 3	44	0 03	0 05	0 2	0
[illegible] d	105	1 fillet, 3 x 3 x ½ in	214	23 5	44	1 4	139	0 17	0 13	2 6	0
[illegible]	90	1 serving, 4 from a pound	205	21 0	[illegible]	0 8	497	0 05	0 06	8 8	0
[illegible]	100	3 sl, 4¾ x 4 x ⅛ in	397	23 0	10	2 9	0	0 54	0 21	4 2	0
[illegible]	100	⅓ heart, 3 in diam x 3¼ in	108	16 9	9	4 6	30	0 58	0 89	7 8	6
[illegible]	21	1 tbsp, level	62	0 1	1	0 2	0	tr	0 01	tr	1
[illegible]	150	1 pc, 2 x 7 in of 6½ in melon	49	0 8	26	0 6	60	0 07	0 [illegible]	0 3	34
[illegible] la	100	1/6 of quart	207	4 0	123	0 1	520	0 04	0 19	0 1	1
[illegible]	140	1/6 of quart (from recipe)	278	4 1	124	0 3	550	0 04	0 20	0.2	1
[illegible]	138	½ cup	177	0 4	[illegible]	0 1	90	0 04	0 01	0 1	27
[illegible]	[illegible]	1 tbsp, level	55	0 1	2	0 1	tr	tr	tr.	tr	1
[illegible] al.	20	1 tbsp, level	[illegible]	0	[illegible]	0.1	tr	tr.	tr.	tr.	1
[illegible]	135	⅛ of 1 quart milk	107	4 3	144	0 1	194	0 04	0 21	0 1	tr.
[illegible]	55	½ cup	22	2 1	124	1.2	4,610	0 04	0 12	0 95	[illegible]
[illegible]	100	⅔ cup, diced	141	15 0	9	7 9	1,150	0 37	2 55	6 4	13
[illegible]	77	½ cup, diced	23	1 6	35	0 45	tr	0 03	0 03	0 15	28

[illegible] chop, cooked, E.P.	70	2 chops, ⅜ in. thick	256	15.8	18	2.2	0	0.09	0.16	3.8	0
[illegible] roasted . . .	100	1½ slices, 3 x 3 x ⅛ in.	274	24.0	10	3.1	0	0.14	0.25	5.1	0
[illegible] . .	14	1 tbsp	126	0	0	0	0	0	0	0	0
[illegible] .	110	½ cup	990	0	0	0	0	0	0	0	0
[illegible]e, fresh	15	1 tbsp	4	0.1	2	tr	[illegible]	0.01	tr.	tr	7
[illegible]e, fresh	100	½ cup, scant	24	0.4	14	0.1	0	0.04	tr.	0.1	[illegible]
[illegible]d, cooked	95	½ cup (whole seeds)	101	7.5	18	2.2	170	0.13	0.06	0.5	0
[illegible]aded, raw,	[illegible]	2 large, or 4 small leaves	7	0.6	11	0.2	270	0.02	0.04	0.1	4
[illegible]se green leaf	50	2 large, or 4 small leaves	7	0.6	31	1.55	[illegible]	0.02	0.04	0.1	9
[illegible] fried	74	2 sl., 3 x 2¼ x ⅜ in.	172	17.5	7	5.8	37,315	0.18	2.56	10.1	20
[illegible] fried	74	2 sl., 3 x 2¼ x ⅜ in.	170	17.5	9	15.5	12,070	0.21	2.30	12.3	10
[illegible]nned	100	⅔ cup meat	92	18.4	65	0.8		0.03	0.07	2.2	
[illegible]s, canned, juice pack	100	½ cup, scant	49	1.0	29	1.0	130	0.01	0.04	0.2	[illegible]
	100	⅔ cup	62	1.0	35	1.2	200	0.01	0.07	0.3	24
[illegible]											
[illegible]d, cooked	140	1 cup 1 in. pc., or elbow	209	7.1	13	0.8	0	0.03	0.02	0.7	0
[illegible] cooked	140	1 cup 1 in. pc., or elbow	209	7.1	13	1.5	0	0.24	0.15	2.0	0
[illegible]h cheese	220	1 cup	464	17.8	420	1.1	990	0.07	0.35	0.9	tr.
[illegible] fortified*	[illegible]	1 avg. pat	72	tr	2	0	330	0	0	0	0
[illegible] fortified	14	1 tbsp	101	0.1	3	0	460	0	0	0	0
[illegible] roiled	[illegible]	1 pc. 4 x 2 x ¾ in.	273	21.1	6	1.1	509	0.19	0.31	7.1	0
[illegible]											
[illegible]e, fresh	244	8 oz., 1 cup or full glass, or ½ pint	166	8.5	288	0.2	390	0.09	0.42	0.3	3
Skim, or buttermilk	246	1 cup	87	8.6	303	0.2	10	0.09	0.44	0.3	3
Half and Half	242	1 cup	330	7.7	261	0.1	1,190	0.08	0.38	0.2	3
Evaporated	126	½ cup, or 1 cup reconstituted	173	8.8	306	0.2	504	0.06	0.44	0.2	[illegible]
Condensed (sweetened)	[illegible]	1 tbsp	64	1.1	55	[illegible]	86	0.01	0.08	[illegible]	tr
Dried, whole	8	1 tbsp	39	2.1	76	[illegible]	110	0.02	0.12	0.1	1
Dried, skim . .	7.5	1 tbsp	[illegible]	2.7	98	[illegible]	tr	0.03	0.15	0.1	1
Malted, plain, dry . .	9	1 tbsp	35	1.3	26	0.2	92	0.03	0.05		0

* Almost all margarines now on sale are fortified to contain 15,000 I.U. of vitamin A per pound.

Table 28. Nutritive Values of Foods in Average Servings [illegible] Common Measures (Continued)

Food	Weight	Approximate Measure	Calories	Protein	Minerals: Calcium	Minerals: Iron	Vitamins: Vitamin A	Vitamins: Thiamine	Vitamins: Riboflavin	Vitamins: Niacin	Vitamins: Ascorbic acid
	[illegible]			[illegible]	mg	mg	I U	mg	mg	mg	mg
Molasses											
Light	20	1 tbsp	50		33	0.9		0.01	0.01	tr.	
Medium	[illegible]	1 tbsp	46		38	1.2					
Blackstrap	[illegible]	1 tbsp	43		116	2.3		0.06	0.05	0.4	
Muffins											
Bran	[illegible]	1 medium	106	2.9	32	0.7	193	0.07	0.08	0.8	0
Cornmeal (yellow)	45	1 medium	128	3.1	30	0.7	220	0.08	0.10	0.6	0
White flour, enriched	40	1 medium	120	3.2	30	0.7	193	0.08	0.09	0.6	0
Mustard greens, cooked	100	½ cup	22	2.3	220	2.9	7,180	0.06	0.18	0.7	45
Noodles, egg											
unenriched	160	1 cup, cooked	107	3.5	6	0.6	60	0.05	0.03	0.6	0
enriched	160	1 cup, cooked	107	3.5	6	0.8	60	0.22	0.10	1.7	0
Nuts, mixed, shelled .	15	8–12 nuts	94	2.5	14	0.5	3	0.09	0.02	0.6	tr.
Oatmeal See under Cereals											
Oil, salad [illegible] cooking	14	1 tbsp	124	tr	0	0	0	0	[illegible]	0	0
Oil, salad or cooking	110	½ cup	972	tr	0	0	0	0	0	0	0
Okra, cooked	85	8 pods, 3 [illegible] long	28	1.5	70	0.6	630	0.05	0.05	0.7	17
Olives, green or ripe	10	1 large, or 2 small	7	0.1	5	0.[illegible]	3 ripe 16 green	tr	tr.		
Onions, green (scallions), raw	10	1 medium size	5	0.1	14	0.08	6	tr.	tr	0.02	[illegible]
mature, raw	10	1 tbsp, chopped	4	0.1	3	[illegible]	tr	tr.	[illegible]	tr.	1
mature, cooked	100	½ cup, 2–3 small	38	1.0	32	0.5	50	0.02	0.03	0.2	6
Orange, whole, E P .	150	1 medium, 3 in diam	68	1.4	50	0.6	285	0.12	0.04	0.3	74
Orange juice, fresh . ..	185	6 oz, ¾ cup, small glass	81	1.5	35	0.4	352	0.15	0.06	0.4	[illegible]
canned, unsweetened ...	185	6 oz, ¾ cup, small glass	81	0.5	19	0.6	185	0.13	0.04	0.4	78
frozen, concentrate .	185	6 oz, ¾ cup, small glass as reconstituted	73	1.4	17	0.5	167	0.12	0.03	0.4	71

[illegible] w, meat only	100	5-8 medium	84	9.8	94	5.6	320	0.15	0.20	1.2	
[illegible] Griddle cakes											
[illegible]	3.5	1 tbsp., chopped	1	0.1	7	0.2	290	tr.	0.01	0.1	7
[illegible] oked	78	½ cup	47	0.8	44	0.55	0	0.04	0.09	0.15	10
[illegible] low, fresh, E P	100	1 medium	46	0.5	8	0.6	880	0.02	0.05	0.9	8
[illegible] rup pack	117	2 halves, 2 tbsp. juice	79	0.5	6	0.5	530	0.01	0.02	0.8	5
[illegible] ater pack	100	2 halves, 1-2 tbsp. juice	27	0.5	5	0.4	450	0.01	0.02	0.7	4
[illegible] ried, cooked	102	3-4 halves, 2 tbsp. juice	122	0.8	12	1.8	844	tr	0.05	1.4	4
[illegible] er	[illegible]	1 tbsp.	92	4.2	12	0.3	0	0.02	0.02	2.6	0
[illegible] sted, E P	15	15-17 nuts, no skins	84	4.0	11	0.3	0	0.04	0.02	2.4	0
[illegible] E P	100	1 small pear	63	0.7	13	0.3	20	0.02	0.04	0.1	4
[illegible] rup pack	117	2 halves, 2 tbsp. juice	79	0.2	9	0.2	tr	0.01	0.02	0.2	[illegible]
[illegible] ater pack	100	2 halves, 1 tbsp. juice	31	0.3	8	0.2	tr	0.01	0.02	0.1	2
[illegible] cooked	[illegible]	½ cup	56	3.9	18	1.5	575	0.20	0.11	1.85	12
[illegible], drained solids	[illegible]	½ cup	73	3.6	26	1.7	515	0.09	0.05	0.8	8
[illegible] split (dry wt.)	30	½ cup, cooked	103	7.4	10	1.5	100	0.18	0.06	0.8	0
[illegible]	15	12 halves, or 2 tbsp. chopped	104	1.4	12	0.4	tr	0.10	0.02	0.2	tr
[illegible] een, raw	10	1 tbsp., chopped	3	0.1	1	tr	63	tr	tr	tr	12
[illegible]	65	1 medium shell, baked	17	0.8	7	0.3	480	0.03	0.05	0.3	64
[illegible]	160	1/6 of medium pie	377	3.8	11	0.5	156	0.05	0.03	0.4	1
[illegible] y	160	1/6 of medium pie	365	4.4	25	0.8	193	0.04	0.03	0.6	7
[illegible]	160	1/6 of medium pie	360	4.3	[illegible]	0.6	601	0.04	0.03	0.4	2
[illegible]	150	1/6 of medium pie	266	7.6	111	0.8	305	0.06	0.21	0.2	0
[illegible] eringue	140	1/6 of medium pie	281	3.8	13	0.5	260	0.03	0.05	0.1	1
[illegible]	160	1/6 of medium pie	398	3.9	35	3.4	12	0.11	0.05	0.5	1
[illegible]	150	1/6 of medium pie	330	6.7	103	2.2	2,278	0.06	0.16	0.5	0
[illegible] esh	100	⅓-½ cup no sugar	52	0.4	16	0.3	130	0.08	0.02	0.2	24
canned, crushed	130	½ cup, in sirup	102	0.5	38	0.8	105	0.10	0.02	0.2	12
canned, juice pack	100	1 large or [illegible] small slices and 2 tbsp. juice	55	0.5	[illegible]	0.6	80	0.07	0.02	0.2	9
Pineapple juice, canned	187	6 oz., ¾ cup, small glass	91	0.5	27	0.8	150	0.10	0.03	0.3	[illegible]
Plums, fresh	100	2 plums, 2 in. diam.	50	0.7	17	0.5	350	0.06	0.04	0.5	5

Table 28. Nutritive Values of Foods in Average Servings or Common Measures (Continued)

Food	Weight	Approximate Measure	Calories	Protein	Minerals: Calcium	Minerals: Iron	Vitamins: Vitamin A	Vitamins: Thiamine	Vitamins: Riboflavin	Vitamins: Niacin	Vitamins: Ascorbic acid
	gm			gm	mg	mg	I U	mg	mg	mg	mg
Pork chop, shoulder, fried	[illegible]	1 medium large chop	310	17.4	12	2.6	0	0.59	0.17	3.6	0
Pork loin, roasted	90	2 sl, 3½ x 3 x ¼ in	300	20.7	10	2.7	0	0.75	0.22	4.5	0
Potatoes, white, baked	100	1 medium, without skin	[illegible]	2.4	13	0.8	20	0.11	0.05	1.4	17
boiled, peeled before cooking	100	1 medium	[illegible]	2.0	11	0.7	20	0.09	0.03	1.0	14
mashed	100	½ cup, 2 hp tbsp with milk and margarine	123	2.1	27	0.6	260	0.08	0.05	0.8	7
Potatoes, sweet See Sweet Potatoes											
Potato chips	20	10 chips, 2 in diam	108	1.3	6	0.4	10	0.04	0.02	0.6	[illegible]
Prunes, dried, stewed, unsweetened	75	4 medium, 2 tbsp juice	86	0.7	17	1.3	545	0.02	0.04	0.4	tr
Prune juice, canned	180	6 oz, ¾ cup, small glass	127	0.7	45	3.2		0.03	0.14	0.75	1
Prune whip	67	½ cup	100	1.9	17	1.2	580	0.02	0.07	0.5	2
Puddings											
Brown Betty, apple	140	½ cup	254	2.9	30	0.8	200	0.08	0.07	0.7	tr.
Cornstarch, caramel	140	½ cup	207	4.3	165	0.8	194	0.04	0.21	0.1	0
Cornstarch, chocolate	144	½ cup	219	4.5	147	0.2	196	0.04	0.22	0.2	0
Lemon sponge [illegible] snow	130	½ cup, plain	114	3.1	4	0.1	0	0.01	0.02	tr	[illegible]
Rice, with raisins	145	¾ cup, baked	249	6.8	205	0.6	265	0.08	0.29	0.4	2
Tapioca, minute	105	½ cup, plain	133	4.9	105	0.5	313	0.03	0.19	0.1	1
Pumpkin, canned	288	1 cup	76	2.3	46	1.6	7,750	0.04	0.14	1.2	
Radishes, red, raw	20	2 small, 1 [illegible] diam	4	0.2	[illegible]	0.2	6	tr	tr	0 [illegible]	5
Raisins, seeded	10	1 tbsp	26	0.2	8	0.3	tr	0.02	0.01	tr.	tr.
Raisins, seeded	40	¼ cup	107	0.9	31	1.3	20	0.06	0.03	0.2	tr
Raspberries, black, fresh	100	⅔ cup	74	1.5	40	0.9	0	0.02	0.07	0.3	24
red, fresh	100	¾ cup	[illegible]	1.2	40	0.9	130	0.02	0.07	0.3	24
canned, juice pack	100	½ cup, scant	48	0.8	24	0.6	70	0.01	0.04	0.2	10

Rhubarb, cooked, sweetened	135	½ cup fruit and sirup	137	0.3	*	0.2	16	tr		tr	2
Rice (dry weight)											
Brown	28.35	¾ cup, cooked	102	2.1	11	0.6	[illegible]	0.09	0.01	1.3	0
Converted	28.35	¾ cup, cooked	103	2.1	7	0.2	0	0.06	0.01	1.1	0
White	28.35	¾ cup, cooked	103	2.1	7	0.2	0	0.[illegible]	0.01	0.5	0
White, pre-cooked	28.35	⅔ cup, cooked	108	2.5	6	0.2	0	0.01	0.01	tr.	0
Rolls											
White, hard	35	1 medium, no milk or butter	95	2.8	8	0.6	0	0.08	0.05	0.8	0
Soft	35	1 cloverleaf	122	3.1	28	0.7	109	0.11	0.09	0.8	0
Rutabagas, cooked	80	½ cup, diced (yellow turnip)	26	0.6	44	0.3	280	0.04	0.06	0.6	17
Salad dressings											
Boiled, home cooked	17	1 tbsp	28	0.8	15	0.1	80	0.01	0.03	[illegible]	tr.
French, avg commercial	15	1 tbsp	59	0.1	0	0	0	0	0	0	0
Low calorie, French type, avg coml	15	1 tbsp	1 8								
Mayonnaise, avg coml	15	1 tbsp	58	0.2	1	0.1	30	tr	tr	0	0
Low calorie, mayonnaise type, avg coml	15	1 tbsp	16								
Salmon, fresh, baked	95	1 avg, 4 oz before cooking	291	21.2	23	0.6	460	0.12	0.24	8.1	0
canned, pink	100	⅔ cup (no bones)	143	20.5	†	0.8	70	0.03	0.18	8.0	0
canned, sockeye or red	100	⅔ cup (no bones)	173	20.2	†	1.2	230	0.04	0.16	7.3	0
Sauces											
Butterscotch sauce	44	2 tbsp	203	0.5	41	1.4	296	tr	tr	tr	tr.
Cheese sauce	75	¼ cup scant	130	5.9	176	0.2	412	0.02	0.16	0.1	tr.
Chocolate sauce	39	2 tbsp	87	1.4	40	0.2	109	0.01	0.05	0.1	tr.
Custard sauce	72	¼ cup	85	3.7	78	0.4	235	0.03	0.24	0.1	tr.
Hard sauce	21	2 tbsp	97	0.1	2	[illegible]	231	tr	tr	tr	0
Hollandaise, true	50	¼ cup, scant	180	2.2	23	0.9	1,027	0.03	0.04	tr	tr
Tartar sauce	20	1 tbsp	[illegible]	0.2	4	0.2	55	tr	tr	tr	1
Tomato sauce	[illegible]	¼ cup	79	1.1	7	0.4	866	0.01	0.03	0.5	5
White sauce, medium	66	¼ cup	107	2.6	[illegible]	0.2	[illegible]	0.02	0.10	0.2	tr.
White sauce, thin	[illegible]	¼ cup	74	2.4	73	0.1	213	0.02	0.10	0.1	tr
Sauerkraut, canned	100	⅔ cup, drained solids	22	1.4	36	0.5	40	0.03	0.06	0.1	16
Sausages											
Bologna	30	1 sl, 4½ in diam x ⅛ in	66	4.4	3	0.7	0	0.05	0.06	0.8	0
Frankfurter, cooked	50	1 average	124	7.0	3	0.6	0	0.08	0.09	1.2	0
Liverwurst	30	1 sl, 3 in diam x ¼ in	79	5.0	3	1.6	1,725	0.05	0.34	1.4	0
Luncheon meat	[illegible]	1 sl, ⅛ in thick	81	4.6	6	0.4	0	0.11	0.15	1.1	0

* Calcium not available due to presence of oxalic acid

† Calcium content of canned salmon is chiefly in the bones, if bones are discarded, the calcium content is low

Table 28. Nutritive Values of Foods in Average Servings in Common Measures (Continued)

Food	Weight	Approximate Measure	Calories	Protein	Minerals: Calcium	Minerals: Iron	Vitamins: Vitamin A	Vitamins: Thiamine	Vitamins: Riboflavin	Vitamins: Niacin	Vitamins: Ascorbic acid
	gm			gm	mg	mg	I U	mg	mg	mg.	mg
Sausages (*continued*)											
Pork sausage, cooked	40	2 links or 1 patty 2 in diam	186	6.5	4	1.0	0	0.19	0.09	0.3	0
Salami ..	[illegible]	1 sl, 3¾ in diam x ¼ in	130	7.2	4	1.1	0	0.07	0.06	0.9	0
Scallops, fried	145	5–6 medium pieces	427	23.8	41	3.1	0	0.09	0.17	2.3	0
Sherbet, milk, avg coml	96	½ cup	118	1.4	48	tr.	0	0.02	0.07	0	0
Shrimps, canned, solids	100	8–12 shrimps	127	26.8	115	3.1	60	0.01	0.03	2.2	0
Sirup, table blends	20	1 tbsp	57	0	9	0.8	0	0	tr	tr	0
Soups, canned, ready to serve											
Bean	250	1 cup	191	8.5	95	2.8		0.10	0.10	0.8	
Bouillon, broth or consomme	240	1 cup	9	2.0	2	1.0	0	0	0.05	0.6	0
Chicken	250	1 cup	75	3.5	20	0.5		0.02	0.12	1.5	
Clam chowder	255	1 cup	86	4.6	36	3.6					
Cream soups (asparagus, celery, mushroom)	255	1 cup	201	7.1	217	0.5	200	0.05	0.20	0.1	0
Tomato	245	1 cup	90	2.2	24	1.0	1,230	0.02	0.10	0.7	10
Vegetable	250	1 cup	82	4.2	32	0.8		0.05	0.08	1.0	8
Spinach, cooked	100	½ cup	23	2.8	*	1.8	10,600	0.07	0.18	0 [illegible]	27
Squash, summer, cooked	100	½ cup, scant	16	0.6	15	0.4	260	0.04	0.07	0.6	11
Squash, winter, cooked	100	½ cup (yellow)	47	1.9	24	0.8	6,190	0.05	0 [illegible]	0.6	7
Strawberries, fresh	100	10 large	37	0.8	28	0.8	60	0.03	0.07	0.3	60
Sugar											
Brown, dark	110	½ cup, firmly packed	407	0	[illegible]	2.85	0	0	0	0	0
White, granulated	100	½ cup	385	0	0	0	0	0	0	0	0
White, granulated	12	1 tbsp, or 3 level tsp.	48	0	0	0	0	0	0	0	0
White, loaf	6–8	1 cube or domino	24–32	0	0	0	0	0	[illegible]	0	0
Sweet potatoes, baked, E P	120	1 avg, 5 in long, 2 in diam	183	2.6	44	1.1	11,410	0.12	0.08	0.9	28
candied....	175	1 small, 3½ x 2¼ in.	314	2.6	63	1.1	10,940	0 [illegible]	0.07	0.9	16

T... fresh ... cooked	150 140	1 medium, 2 x 2½ in ½ cup solids and liquid	30 23	1 5 1 2	16 13	0 9 0 75	1,640 1,270	0 08 0 07	0 06 0 04	0 8 0 85	35 20
... canned	180	6 oz , ¾ cup, small glass	38	1 8	13	0 75	1,905	0 09	0 05	1,35	28
...ned	100	⅗ cup, solids without oil	198	29 0	8	1 4	80	0 05	0 12	12 8	0
...ed	100	3 sl , 3½ x 2½ x ⅛ in	200	30 9	30	5 1	0–20	0 08	0 17	9 8	0
... cooked	[illegible]	½ cup	22	2 1	188	1 8	7,685	0 04	0 30	0 5	44
..., cooked	100	⅔ cup, diced	27	0 8	40	0 5	tr	0 04	0 06	0.4	18
...eaded	92	1 average serving, baked	217	23 8	22	3 0	0	0 10	0 25	6 5	0
...ed	[illegible]	3 sl., 3 x 2 x ⅛ in	210	25 2	30	8 7	0	0 12	0 28	7.2	0
W...	75	1 waffle, 6 in diam	216	7 0	144	0 8	270	0 05	0 14	0,3	0
W...sh	15	8–15 halves, 2 tbsp chopped	98	2 3	12	0 3	5	0 07	0 02	0 2	tr.
...w	10	10 avg. sprigs	2	0 2	20	0 2	472	tr	0 02	0 1	8
...p	100	½ cup, cubes or balls	28	0 5	7	0 2	590	0 05	0 05	0 2	6
Wa...p	600	1 sl 6 in diam x 1½ in	168	3 0	72	1 2	3,540	0 30	0 30	1 2	36
W...	10	1 tbsp , rounded	36	2 5	8	0 8	0	0 20	0 08	0 5	0
Y... ...st ...ers' ...lets	10 8	1 cake, compressed 1 tbsp 1 tablet	10 22	1 3 3 0	3 8	0 6 1 5	0 0 0	0 05 0 78 0 06	0 25 0 44 0 02	3 4 2 9 0 15	0 0 0

* Calcium present is mostly in nonutilizable form

Table 29. Alcoholic Beverage, Caloric Values of Usual Portions*

	Approximate Measure	Weight	Alcohol	Calories
Distilled liquors:		gm.	gm.	
Liqueurs:				
Anisette.	1 cordial glass	20	7.0	75
Apricot brandy	1 cordial glass	20	6 0	65
Benedictine	1 cordial glass	20	6.6	70
Creme de menthe	1 cordial glass	20	6.0	70
Curacao	1 cordial glass	20	6.0	60
Brandy.	1 brandy glass	30	10.5	75
Gin, dry	1 jigger, 1½ oz	43	15 1	107
Rum.	1 jigger, 1½ oz.	43	15.1	107
Whiskey, rye	1 jigger, 1½ oz.	43	17 2	122
Whiskey, Scotch.	1 jigger, 1½ oz.	43	15 1	107
Wines				
California, red	1 wine glass	100	10.0	73
California, sauterne	1 wine glass	100	10 5	85
Champagne, domestic	1 wine glass	100	11.0	90
French vermouth or Madeira	1 wine glass	100	15 0	108
Port or Muscatelle	1 wine glass	100	15 0	160
Sherry, dry	1 wine glass	100	17.0	140
Vermouth, Italian	1 wine glass	100	18 0	170
Malt liquors (American):				
Ale, mild	Large glass, 8 oz.	230	8.9	100
Ale, mild.	1 bottle, 12 oz.	345	13.1	148
Beer, avg.	Large glass, 8 oz.	240	8.9	114
Beer, avg	1 bottle, 12 oz.	360	13.3	173
Mixed drinks, Cocktails (approx. from recipes)				
Alexander	1 cocktail glass	75		220
Bronx.	1 cocktail glass			230
Daiquiri	1 cocktail glass		15.1	125
Egg nog, Christmas type	1 punch cup	125	15.0	338
Gin rickey.	1 glass		21 0	153
High ball.	1 glass		24 0	170
Manhattan.	1 cocktail glass		19.2	167
"			18 5	143
"			29.2	217
			24 [illegible]	183
			21 5	177
			21 0	163
			21.5	182

* Figures chiefly from Bowes and Church, *Food Values of Portions Commonly Used*, p. 9, 1951.

Table [illegible] Food Plan at Low Cost: Suggested Weekly Quantities of Food (as Purchased, Assuming Average Choices Within Groups) for 19 Sex-Age Groups*

Family members	*Milk, cheese, ice cream*	*Meat, poultry, fish*		*Eggs*	*Dry beans, peas, nuts*		*Flour, cereal, baked goods*		*Citrus fruit, tomatoes*		*Dark-green and deep-yellow vegetables*		*Potatoes*		*Other vegetables and fruit*		*Fats, oils*		*Sugar, sweets*	
	Qt	*Lb*	*Oz*	*No*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb.*	*Oz.*
Children																				
Under 1 year	5½	1	0	5	0	0	0	12	1	8	0	2	0	8	1	0	0	1	[illegible]	2
1–3 years	5½	1	4	5	0	1	1	1	1	8	0	4	0	12	2	4	0	4	[illegible]	4
4–6 years	5½	1	8	5	0	2	2	0	1	12	0	4	1	4	1	4	0	6	0	6
7–9 years	5½	2	0	6	0	4	2	4	2	0	0	8	2	0	1	1	0	8	[illegible]	10
10–12 years	6½	2	4	6	0	6	3	0	2	4	0	8	2	8	5	0	0	8	[illegible]	12
Girls																				
13–15 years	7	2	8	6	0	4	3	0	2	4	0	12	2	8	5	0	0	10	0	12
16–19 years	7	2	8	6	0	4	2	12	2	4	0	12	2	4	4	12	0	6	0	10
Boys																				
13–15 years	7	2	8	6	0	6	4	4	2	8	0	12	3	4	5	4	0	12	0	12
16–19 years	7	3	4	6	0	8	5	1	2	8	0	12	4	12	5	8	0	14	0	14
Women																				
20–34 years	3½	2	8	5	0	4	2	8	2	0	0	12	4	0	5	0	0	6	0	10
35–54 years	3½	[illegible]	8	5	[illegible]	4	2	8	2	0	0	12	1	8	4	8	0	4	0	10
55–74 years	3½	[illegible]	8	5	0	4	2	4	2	[illegible]	0	12	1	4	3	8	0	4	0	6
75 years and over	3½	[illegible]	8	5	[illegible]	4	[illegible]	[illegible]	[illegible]	0	0	12	1	4	3	0	0	4	[illegible]	6
Pregnant	7	2	8	7	0	4	[illegible]	8	3	8	1	8	2	0	5	0	0	6	[illegible]	8
Lactating	10	3	4	7	0	4	3	0	4	[illegible]	1	8	3	4	5	8	0	8	0	10
Men																				
20–34 years	3½	3	12	6	0	6	4	4	2	4	0	12	3	4	5	8	0	[illegible]	1	0
35–54 years	3½	3	8	6	0	6	3	12	2	4	0	12	3	[illegible]	5	0	0	10	0	[illegible]
55–74 years	3½	[illegible]	4	6	0	4	3	8	[illegible]	4	0	12	2	8	4	12	0	10	0	[illegible]
75 years and over	3½	3	4	6	0	4	[illegible]	4	2	0	0	[illegible]	2	4	4	8	0	8	0	10

* Tables 30, 31, and 32 are taken from FOOD, THE YEARBOOK OF AGRICULTURE, U S D A , 1959.

Table 31. Food Plan at Moderate Cost: Suggested Weekly Quantities of Food (as Purchased, Assuming Average Choices Within Groups) for 19 Sex-Age Groups

Family members	*Milk, cheese, ice cream*	*Meat, poultry, fish*		*Eggs*	*Dry beans, peas, nuts*		*Flour, cereal, baked goods*		*Citrus fruit, tomatoes*		*Dark-green and deep-yellow vegetables*		*Potatoes*		*Other vegetables and fruit*		*Fats, oils*		*Sugar, sweets*	
	Qt	*Lb*	*Oz*	*No*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb.*	*Oz.*
Children																				
Under 1 year	6	1	4	6	0	0	0	12	1	8	[illegible]	2	0	8	1	8	0	1	[illegible]	[illegible]
1–3 years	6	1	12	6	0	1	1	0	1	8	0	4	[illegible]	12	2	12	[illegible]	4	[illegible]	4
4–6 years	6	2	4	6	0	1	1	12	2	0	0	4	1	[illegible]	4	[illegible]	0	6	0	10
7–9 years	6	3	0	7	0	2	2	0	2	4	0	8	1	12	4	12	0	10	0	14
10–12 years	6½	4	0	7	0	4	2	12	2	8	0	12	2	4	5	8	0	10	0	14
Girls																				
13–15 years	7	4	8	7	0	2	2	12	2	8	0	12	2	4	5	12	0	12	0	14
16–19 years	7	4	4	7	0	2	2	8	2	8	0	12	2	0	5	8	0	10	0	[illegible]
Boys																				
13–15 years	7	4	12	7	0	4	4	0	2	12	0	12	3	0	6	0	0	14	1	0
16–19 years	7	5	8	7	0	6	5	0	3	0	0	12	4	4	6	4	1	2	1	2
Women																				
20–34 years	3½	4	4	6	0	2	2	4	2	8	0	12	1	8	5	[illegible]	0	8	[illegible]	14
35–54 years	3½	4	4	6	0	2	2	0	2	8	0	12	1	4	5	4	0	8	[illegible]	[illegible]
55–74 years	3½	4	4	6	0	2	1	[illegible]	2	4	[illegible]	12	1	4	4	4	0	6	0	8
75 years and over	3½	3	12	6	0	2	1	12	2	4	0	12	1	[illegible]	3	12	0	6	0	8
Pregnant	7	4	4	7	0	2	2	4	3	8	1	8	1	8	[illegible]	12	0	8	0	12
Lactating	10	5	0	7	0	2	2	12	5	0	1	8	[illegible]	[illegible]	6	4	0	[illegible]	0	12
Men																				
20–34 years	3½	5	8	7	0	4	4	0	2	12	0	12	3	0	6	8	1	0	1	4
35–54 years	3½	5	4	7	0	4	3	8	2	[illegible]	0	12	[illegible]	8	5	[illegible]	0	14	1	0
55–74 years	3½	5	0	7	0	2	3	4	2	12	0	[illegible]	2	4	5	8	0	12	[illegible]	14
75 years and over	3½	5	0	7	0	2	2	12	2	8	[illegible]	12	[illegible]	0	5	4	0	10	0	12

Table 32 Food Plan at Liberal Cost: Suggested Weekly Quantities of Food (as Purchased, Assuming Average Choices Within Groups) for 19 Sex-Age Groups

Family members	*Milk, cheese, ice cream*	*Meat, poultry, fish*		*Eggs*	*Dry beans, peas, nuts*		*Flour, cereal, baked goods*		*Citrus fruit, tomatoes*		*Dark-green and deep-yellow vegetables*		*Potatoes*		*Other vegetables and fruit*		*Fats, oils*		*Sugar, sweets*	
Children	*Qt*	*Lb*	*Oz*	*No*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb*	*Oz*	*Lb.*	*Oz*
Under 1 year	6	1	4	7	0	0	0	12	1	12	0	2	0	8	1	8	0	2	0	2
1–3 years	6	2	4	7	0	1	1	0	1	12	0	4	0	[illegible]	2	14	[illegible]	4	0	4
4–6 years	6	3	0	7	0	1	1	8	2	4	0	8	0	12	4	8	0	8	0	12
7–9 years	6	3	12	7	0	2	1	12	2	12	0	8	1	8	5	4	[illegible]	10	1	0
10–12 years	6½	4	12	7	0	3	2	12	3	0	0	12	2	4	6	0	0	10	1	0
Girls																				
13–15 years ..	7	5	8	7	0	2	2	8	3	0	0	12	2	4	6	0	0	12	1	2
16–19 years	7	5	4	7	0	2	2	4	3	0	0	12	1	12	5	12	0	10	1	0
Boys																				
13–15 years	7	5	8	7	0	4	4	0	3	4	0	12	3	0	6	8	0	14	1	4
16–19 years	7	6	4	7	0	6	5	0	3	8	0	12	4	4	7	4	1	4	1	2
Women																				
20–34 years	4	4	12	6	0	1	2	0	3	0	0	12	1	4	6	4	0	8	1	2
35–54 years	4	4	12	6	0	1	1	12	3	0	0	[illegible]	1	0	6	0	0	8	1	0
55–74 years	4	4	12	6	0	1	1	8	3	0	0	12	1	0	4	8	0	6	0	12
75 years and over	4	4	4	6	0	1	1	8	3	0	0	12	0	12	4	[illegible]	[illegible]	6	0	10
Pregnant	7	4	12	7	0	1	2	0	4	8	1	8	1	4	6	4	0	8	1	0
Lactating	10	5	12	7	0	2	[illegible]	12	5	8	1	8	2	8	6	4	0	12	1	2
Men																				
20–34 years	4	6	0	7	0	4	3	12	3	0	0	12	2	12	7	12	1	0	1	8
35–54 years	4	5	8	7	0	4	3	8	3	0	0	12	2	4	6	8	0	14	1	4
55–74 years	4	5	4	7	0	2	3	4	3	0	0	12	2	0	6	0	0	12	1	2
75 years and over	4	5	4	7	0	2	2	12	2	12	0	12	1	12	5	12	0	10	1	0

Table 33. Food Groups and Approximate Number of Servings per Person, Low-Cost and Moderate-Cost Plans*

Food Groups	Number of Servings per Person	
	Low-Cost Plan	*Moderate-Cost Plan*
Leafy, green, and yellow vegetables	7 to 9 servings a week	10 to 12 servings a week
Citrus fruit, tomatoes	Children, 7 servings a week	Children, 8 to 9 servings a week
	Pregnant and nursing women, 9 to 12 servings a week	Pregnant and nursing women, 12 to 15 servings a week
	Other adults, 6 or 7 servings a week	Other adults, 7 to 9 servings a week
Potatoes, sweet potatoes	10 to 12 servings a week	7 to 9 servings a week
Other vegetables and fruit	7 servings a week	10 to 12 servings a week
Milk, cheese, ice cream (in terms of fluid milk)	Children, about 3½ cups of milk a day	Children, 3½ to 4 cups of milk a day
	Pregnant women, a little more than 1 quart daily	Pregnant women, a little more than 1 quart daily
	Nursing women, 1½ quarts a day	Nursing women, 1½ quarts a day
	Other adults, 2½ to 3 cups a day	Other adults, 2½ to 3 cups a day
Meat, poultry, fish	5 or 6 servings a week	7 or 8 servings a week
Eggs	5 eggs a week	7 eggs a week
Dry beans and peas, nuts	2 to 4 servings a week	1 to 2 servings a week
Flour, cereal, baked goods (whole-grain, enriched, restored)	Bread at every meal and also a cereal dish once a day	At every meal
Fats, oils	Throughout the week as desired, butter or margarine *daily*	Throughout the week as desired, butter or margarine *daily*
Sugar, sirup, preserves	Throughout the week as desired	Throughout the week as desired

* From U S Dept Agric, Misc Pub No 662, rev 1955

Table 34. Average Weights of Men[1]

Graduated Weights (in indoor clothing) in Pounds

	Age Groups							
Height	*15–16*	*17–19*	*20–24*	*25–29*	*30–39*	*40–49*	*50–59*	*60–69*
5' 0"	98	113	122	128	131	134	136	133
1"	102	116	125	131	134	137	139	136
2"	107	119	128	134	137	140	142	139
3"	112	123	132	138	141	144	145	142
4"	117	127	136	141	145	148	149	146
5"	122	131	139	144	149	152	153	150
6"	127	135	142	148	153	156	157	154
7"	132	139	145	151	157	161	162	159
8"	137	143	149	155	161	165	166	163
9"	142	147	153	159	165	169	170	168
10"	146	151	157	163	170	174	175	173
11"	150	155	161	167	174	178	180	178
6' 0"	154	160	166	172	179	183	185	183
1"	159	164	170	177	183	187	189	188
2"	164	168	174	182	188	192	194	193
3"	169	172	178	186	193	197	199	198
4"	*	176	181	190	199	203	205	204

[1] Excerpted from 1959 BUILD AND BLOOD PRESSURE STUDY, published by Society of Actuaries, October 1959

* Average weights omitted in classes having too few cases

Table 35 Average Weights of Women[1]

Graduated Weights (in indoor clothing) in Pounds

	Age Groups							
Height	*15–16*	*17–19*	*20–24*	*25–29*	*30–39*	*40–49*	*50–59*	*60–69*
4'10"	97	99	102	107	115	122	125	127
11"	100	102	105	110	117	124	127	129
5' 0"	103	105	108	113	120	127	130	131
1"	107	109	112	116	123	130	133	134
2"	111	113	115	119	126	133	136	137
3"	114	116	118	122	129	136	140	141
4"	117	120	121	125	132	140	144	145
5"	121	124	125	129	135	143	148	149
6"	125	127	129	133	139	147	152	153
7"	128	130	132	136	142	151	156	157
8"	132	134	136	140	146	155	160	161
9"	136	138	140	144	150	159	164	165
10"	*	142	144	148	154	164	169	*
11"	*	147	149	153	159	169	174	*
6' 0"	*	152	154	158	164	174	180	*

[1] Excerpted from 1959 BUILD AND BLOOD PRESSURE STUDY, published by Society of Actuaries, October 1959

* Average weights omitted in classes having too few cases

Table 36. Weight–Height–Age Table for Boys from Birth to School Age*

Height, inches	*Average weight, pounds*	*Age*											
		1 *mo.*	3 *mo.*	6 *mo*	9 *mo.*	1 *yr.*	1½ *yr.*	2 *yr.*	2½ *yr.*	3 *yr.*	4 *yr.*	5 *yr.*	6 *yr.*
20	8	8											
21	9½	9	10										
22	10½	10	11										
23	12	11	12	13									
24	13½	12	13	14									
25	15	13	14	15	16								
26	16½		15	17	17	18							
27	18		16	18	18	19							
28	19½			19	19	20	20						
29	20½			20	21	21	21						
30	22			22	22	22	22	22					
31	23				23	23	23	23	24				
32	24½				24	24	24	25	25				
33	26					26	26	26	26	26			
34	27						27	27	27	27			
35	29½						29	29	29	29	29		
36	31							30	31	31	31		
37	32							32	32	32	32	32	
38	33½								33	33	33	34	
39	35								35	35	35	35	
40	36½									36	36	36	36
41	38										38	38	38
42	39½										39	39	39
43	41½										41	41	41
44	43½											43	43
45	45½											45	45
46	48												48
47	50												50
48	52½												52
49	55												55

Figures represent weight in pounds Weights are net up to and including 34 inches height, above this with ordinary clothing but without shoes, coats or sweaters
Weight to nearest pound.
Height to nearest inch.
Age to nearest birthday.

* Tables prepared by Robert M. Woodbury, Ph D. and reprinted by permission of Children's Bureau, U. S. Dept. of Interior.

Table 37. Weight–Height–Age Table for Girls from Birth [illegible] School Age*

Height, inches	Average weight, pounds	Age: 1 mo.	3 mo.	6 mo	9 mo	1 yr	1½ yr	2 yr.	2½ yr.	3 yr.	4 yr	5 yr	6 yr
20	8	8											
21	9	9	10										
22	10½	10	11										
23	12	11	12	13									
24	13½	12	13	14	14								
25	15	13	14	15	15								
26	16½		15	16	17	17							
27	17½		16	17	18	[illegible]							
28	19			18	19	[illegible]	19						
29	20			19	20	20	20						
30	21½			21	21	21	21	21					
31	22½				22	22	23	23	23				
[illegible]	24					23	24	24	24	25			
[illegible]	25						25	25	25	26			
34	26½						26	26	26	27			
35	29						29	29	29	29	29		
36	30							30	30	30	30	31	
37	31½							31	31	31	31	32	
38	32½								33	33	33	33	
39	34								34	34	34	34	34
40	35½									35	36	36	36
41	37½										37	37	37
42	39										39	39	39
43	41										40	41	41
44	42½											42	42
45	45												45
46	47½												47
47	50												50
48	52½												52

Figures represent [illegible]

Table 38. Weight–Height–Age Table for Boys of School Age[1]

Height, inches	Average weight for height, pounds	5 yr.	6 yr.	7 yr.	8 yr.	9 yr.	10 yr.	11 yr.	12 yr.	13 yr.	14 yr.	15 yr.	16 yr.	17 yr.	18 yr.	19 yr.	Height, inches
38	34	34	34*														38
39	35	35	35														39
40	36	36	36*														40
41	38	38	38	38*													41
42	39	39	39	39*	39*												42
43	41	41	41	41*	41*												43
44	44	44	44	44	44*												44
45	46	46	46	46	46*	46*											45
46	48	47*	48	48	48	48*											46
47	50	49*	50	50	50	50*	50*										47
48	53		52	53	53	53	53*										48
49	55		55	55	55	55	55	55*									49
50	58		57*	58	58	58	58	58*	58*								50
51	61			63	61	61	61	61	61*								51
52	64			64	64	64	64	64	64	64*							52
53	68			66*	67	67	67	67	68	68*							53
54	71				70	70	70	70	71	71	72*						54
55	74				72*	72	73	73	74	74	74*						55
56	78				75*	76	77	77	77	78	78	80*					56
57	82					79*	80	81	81	82	83	83*					57
58	85					83*	84	84	85	85	86	87					58
59	89						87	88	89	89	90	90	90				59

60	94					91*	[illegible]	92	93	94	95	96				60
61	99						[illegible]	96	97	99	100	103	106*			61
62	104						100*	101	102	103	104	107	111	116*		62
63	*111*						105*	106	107	108	110	113	118	123	127*	63
64	117							109	111	113	115	117	121	126	130*	64
65	123							114*	117	118	120	122	127	131	134	[illegible]
66	129								119	122	125	128	132	136	139	66
67	133								124*	128	130	134	136	139	142	67
68	139									134	134	137	141	143	147	[illegible]
69	144									137	139	143	146	149	152	[illegible]
70	147									143	144	145	148	151	155	70
71	*152*									148*	150	151	152	154	159	71
72	157										153	155	156	158	163	72
73	163										*157**	*160*	162	*164*	*167*	73
74	169										160*	164	168	170	171	74

Age—Years		6	7	8	9	10	11	12	13	14	15	16	17	18	19
Average height (inches)	Short	43	45	47	49	51	53	54	56	58	60	62	64	65	65
	Medium	46	48	50	52	54	56	58	60	63	65	67	68	69	69
	Tall	49	51	53	55	57	59	61	64	67	70	72	72	73	73
Average annual gain (lb)	Short	3	4	5	5	5	4	8	9	11	[illegible]	13	7	3	
	Medium	4	5	6	6	6	7	9	11	15	11	8	4	3	
	Tall	5	7	7	7	7	8	12	16	11	9	7	3	4	

The figures represent weight in pounds; age at nearest birthday, height at nearest inch, weight at nearest pound.

Starred figures are estimated weights for children who are taller or shorter than usual for the age group. All unstarred figures represent actual averages

Weight in ordinary clothing but without shoes, coats, or sweaters

[1] Tables prepared by Bird T. Baldwin, Ph D, Iowa Child Welfare Research Station, State University of Iowa, and Thomas D. Wood, M.D, Columbia University. Reprinted by courtesy of the American Child Health Association

Table 39. Weight–Height–Age Table for Girls of School Age[1]

Height, inches	Average weight for height, pounds	5 yr.	6 yr	7 yr	8 yr	9 yr.	10 yr	11 yr.	12 yr.	13 yr.	14 yr.	15 yr.	16 yr.	17 yr.	18 yr.	Height, inches
38	33	33	33													38
39	34	34	34													39
40	36	36	36	36*												40
41	37	37	37	37*												41
42	39	39	39	39–												42
43	41	41	41	41	41*											43
44	42	42	42	42	42*											44
45	45	45	45	45	45	45*										45
46	47	47*	47	47	48	48*										46
47	50	49*	50	50	50	50	50*									47
48	52		52	52	52	52	53*	53*								48
49	55		54	54	55	55	56	56*								49
50	58		56*	56	57	58	59	61	62*							50
51	61			59	60	61	61	63	65							51
52	64			63*	64	64	64	65	67							52
53	68			66*	67	67	68	68	69	71*						53
54	71				69	70	70	71	71	73*						54
55	75				72*	75	74	74	75	77	78*					55
56	79					76	78	78	79	81	83*					56
57	84					80*	82	82	82	84	88	92*				57
58	89						84	86	86	88	93	96*	101*			58
59	95						87	87	90	92	96	100	103*	104		59

60	101						91*	95	[redacted]	97	101	105	[redacted]	109	111*	[redacted]
61	108							99	100	101	105	108	112	113	116	61
62	114							104*	[redacted]	106	109	113	115	117	118	[redacted]
63	118								110	110	112	116	117	119	120	63
64	121								114*	115	117	119	120	122	123	64
65	125								118*	120	121	122	123	125	126	[redacted]
66	129									124	124	125	128	129	130	66
67	133'									128*	130	131	133	133	135	67
68	138									131*	133	135	136	138	138	[redacted]
69	142										135*	137*	138*	140*	142*	69
70	144										136*	138*	140*	142*	144*	70
71	145										138*	140*	142*	144*	154*	71

Age—Years		*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	
Average height (inches)	Short	43	45	47	49	50	52	54	57	59	60	61	61	61	
	Medium	45	47	50	52	54	56	58	60	62	63	64	64	64	
	Tall	47	50	53	55	57	59	62	64	66	66	67	67	67	
Average annual gain (lb)	Short	4	4	4	5	6	6	10	13	[redacted]	7	2	1		
	Medium	5	5	6	7	8	10	13	[redacted]	6	4	3	1		
	Tall	6	8	8	9	11	13	9	8	4	4	1	1		

The figures represent weight in pounds, [redacted] at nearest birthday, height at nearest inch, weight at nearest pound.

Starred figures are estimated weights for children who are taller [redacted] shorter than usual for the age group All unstarred figures represent actual averages

Weight in ordinary clothing but without shoes, coats, or sweaters

[1] Tables prepared by Bird T Baldwin, Ph D, Iowa Child Welfare Research Station, State University of Iowa, and Thomas D. Wood, M D, Columbia University. Reprinted by courtesy of the American Child Health Association.

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